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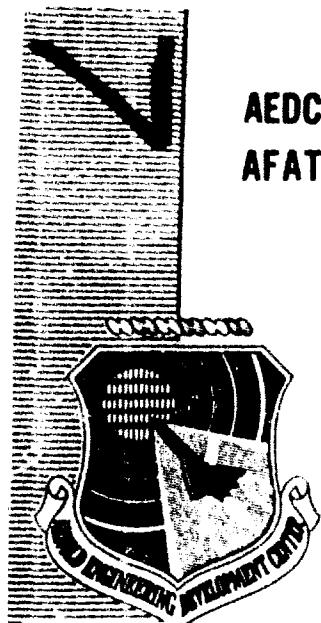
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AEDC-TR-76-147
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(2)

**AERODYNAMIC LOADS AND SEPARATION
CHARACTERISTICS OF THE BLU-27B/B,
MK-82SE, AND GBU-8 WEAPONS IN THE
F-16 AIRCRAFT FLOW FIELD AT
MACH NUMBERS FROM 0.4 TO 1.2**

PROPULSION WIND TUNNEL FACILITY
ARNOLD ENGINEERING DEVELOPMENT CENTER
AIR FORCE SYSTEMS COMMAND
ARNOLD AIR FORCE STATION, TENNESSEE 37389

AD E 014360

October 1976

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AIR FORCE ARMAMENT LABORATORY (AFATL/DLJC)
EGLIN AIR FORCE BASE, FLORIDA 32542

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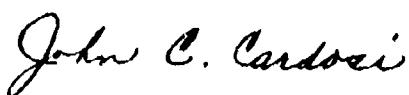
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APPROVAL STATEMENT

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER



JOHN C. CARDOSI
Lt Colonel, USAF
Chief Air Force Test Director, PWT
Directorate of Test



ALAN L. DEVEREAUX
Colonel, USAF
Director of Test

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20. ABSTRACT (Continued)

0.4 to 1.2 for various weapons loading configurations of the F-16. Other variables included aircraft angles of attack from 0 to 10 deg and wing leading-edge-flap deflection angles of 0, 4, and 15 deg.



PREFACE

The work reported herein was conducted by the Arnold Engineering Development Center (AEDC), Air Force Systems Command (AFSC), at the request of the Air Force Armament Laboratory (AFATL/DLJC), under Program Element 62602F, Project 2567, Task 01. The AFATL project monitor was Mr. Al Marrin. The test results were obtained by ARO, Inc. (a subsidiary of Sverdrup & Parcel and Associates, Inc.), contract operator of the AEDC, AFSC, Arnold Air Force Station, Tennessee, under ARO Project No. P41C-C6A. The author of the report was E. G. Allee, Jr., ARO, Inc. Testing was accomplished during the period May 10 through 14, 1976, and the data reduction was completed on June 10, 1976. The manuscript (ARO Control No. ARO-PWT-TR-76-96) was submitted for publication on August 23, 1976.

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1.0 INTRODUCTION

An investigation of the flow-field characteristics in the vicinity of the midwing and inboard weapons stations (wing stations 7 and 6) of the F-16 aircraft was conducted in the Aerodynamic Wind Tunnel (AT) of the Propulsion Wind Tunnel Facility. Aerodynamic loads on the BLU-27B/B, the GBU-8, and the MK-82SE stores positioned at various locations in the aircraft flow field were determined for different combinations of pylons, racks, and weapons. Loads data were also obtained on the MK-82SE with the F-16 wing leading-edge-flaps deflected 0, 4, and 15 deg. A limited number of captive separation trajectories was acquired with the MK-82SE and GBU-8 released from both the midwing and inboard weapons pylons at a simulated altitude of 5,000 ft. Test parameters included Mach numbers from 0.4 to 1.2 and aircraft angles of attack from 0 to 10 deg.

2.0 APPARATUS

2.1 TEST FACILITY

The Aerodynamic Wind Tunnel (AT) is a closed-loop, continuous flow, variable-density tunnel in which the Mach number can be varied from 0.1 to 1.3 and can be set at 1.6 and 2.0 by placing nozzle inserts over the permanent sonic nozzle. At all Mach numbers, the stagnation pressure can be varied from 300 to 3,700 psfa. The test section is a ft square and 12.5 ft long with perforated, variable porosity (0.5- to 10-percent open) walls. It is completely enclosed in a plenum chamber from which the air can be evacuated, allowing part of the tunnel airflow to be removed through the perforated walls of the test section.

Two separate and independent support systems were used to support the models. The parent aircraft model was inverted in the test section and supported by an offset sting attached to the main pitch sector. The store model was supported by the captive trajectory support (CTS)

which extends down from the tunnel top wall and provides store movement (six degrees of freedom) independent of the parent-aircraft model. An isometric drawing of a typical installation is shown in Fig. 1.

Also shown in Fig. 1 is a block diagram of the computer control loop used during testing. The analog system and the digital computer work as an integrated unit and, utilizing required input information, control the store movement. Positioning is accomplished by use of six individual d-c electric motors. Maximum translational travel of the CTS is ± 5 in. from the tunnel centerline in the lateral and vertical directions and 36 in. in the axial direction. Maximum angular displacements are ± 5 deg in pitch and yaw and ± 360 deg in roll. A more complete description of the test facility can be found in the Test Facilities Handbook.¹ A schematic showing the test section details and the location of the models in the tunnel is shown in Fig. 2.

2.2 TEST ARTICLES

Models used during this test were 0.0667-scale replicas of the F-16 aircraft and associated pylons, triple (TER) and multiple (MER) ejection racks, the MK-82SE, BLU-27B/B, and GBU-8 munitions, the AIM-9J missile and wingtip launcher rail, the 370-gal fuel tank, and the ALQ-119-12 ECM pod. Details of these models are presented in Figs. 3, 4, and 5. The leading-edge flaps of the F-16 model could be set at angles of 0, 4, and 15 deg. During the test, the horizontal stabilizers of the F-16 model were removed to avoid interference with the store-model sting support.

¹ Test Facilities Handbook (Tenth Edition). "Propulsion Wind Tunnel Facility, Vol. 4." Arnold Engineering Development Center, May 1974.

Store parameters used in the calculation of the aerodynamic loads and trajectories are included in Table 1. Typical tunnel installation photographs showing the aircraft model, stores, and CTS are shown in Fig. 6. Store orientation and station numbering sequence on the MER and TER are included in Fig. 7. A summary of the various configurations tested is presented in Fig. 8.

2.3 INSTRUMENTATION

A six-component internal strain-gage balance was used to obtain store aerodynamic force and moment data. Translational and angular positions of the store were obtained from CTS analog inputs during separation trajectories and from digital computer commands during aerodynamic testing.

A touch-wire system was used to accurately position the store model with respect to the aircraft model. The system was also electrically wired to automatically stop the CTS motion and give visual indication should the store or its sting support make contact with any surface other than the touch wire.

3.0 TEST DESCRIPTION

3.1 TEST CONDITIONS

A complete test summary and the wind tunnel test conditions are given in Table 2. Aerodynamic loads data were obtained at Mach numbers from 0.4 to 1.2. Separation trajectory data were obtained at Mach numbers from 0.6 to 1.2. Tunnel conditions were held constant at the desired Mach number while the data were obtained. The trajectories were terminated when the store or its sting contacted the aircraft model or when a CTS limit was reached.

3.2 DATA ACQUISITION

3.2.1 Aerodynamic Loads Data

Store aerodynamic data in the free stream and in the aircraft model flow field were obtained in the following manner. After tunnel conditions were established and the aircraft model angle of attack was set (when applicable), the store was set at $\alpha_s = 0$ (free-stream data) or at the carriage position ($X_p = Y_p = Z_p = 0$ for aerodynamic loads data). Operational control of the CTS was then switched to the digital computer, which positioned the store at previously selected locations related to its initial position by commands to the CTS (see block diagram, Fig. 1). At each position set, the wind tunnel operating conditions and the store model forces and moments were measured and recorded. The model aerodynamic loads were then reduced to coefficient form and tabulated point by point by the digital computer.

3.2.2 Trajectory Data

To obtain a trajectory, test conditions were established in the tunnel and the aircraft model was positioned at the desired angle of attack. Operational control of the CTS was then switched to the digital computer which automatically oriented the store model at a position corresponding to the carriage location and then controlled the store movement during the trajectory through commands to the CTS analog system (see block diagram, Fig. 1). Data from the wind tunnel, consisting of measured model forces and moments, wind tunnel operating conditions, and CTS rig positions, were input to the digital computer for use in the full-scale trajectory calculations.

The digital computer was programmed to solve the six-degree-of-freedom equations to calculate the angular and linear displacements of the store relative to the aircraft pylon. In general, the program involves using

the last two successively measured values of each static aerodynamic coefficient to predict the magnitude of the coefficients over the next time interval of the trajectory. These predicted values are used to calculate the new position and attitude of the store at the end of the time interval. The CTS is then commanded to move the store model to this new position, and the aerodynamic loads are measured. If these new measurements agree with the predicted values, the process is continued over another time interval of the same magnitude. If the measured and predicted values do not agree within the desired precision, the calculation is repeated over a time interval one-half the previous value. This process is repeated until a complete trajectory has been obtained.

In applying the wind tunnel data to the calculations of the full-scale store trajectories, the measured forces and moments are reduced to coefficient form and then applied with proper full-scale store dimensions and flight dynamic pressure. Dynamic pressure was calculated using a flight velocity equal to the free-stream velocity component plus the components of store velocity relative to the aircraft, and a density corresponding to the simulated altitude.

The initial portion of each launch trajectory incorporated simulated ejector forces in addition to the measured aerodynamic forces acting on the store. The ejector force was considered to act perpendicularly to the pylon or rack mounting surface. The ejector forces and locations, along with other full-scale store parameters used in the trajectory calculations, are included in Table 1.

3.3 CORRECTIONS

Balance, sting, and support deflections caused by the aerodynamic loads on the store models were accounted for in the data reduction program to calculate the true store-model angles. Corrections were also

made for model weight tares to calculate the net aerodynamic forces on the store model. No correction was made to account for angular deflections of the aircraft model.

3.4 PRECISION OF DATA

Data obtained using the CTS are subject to error from several sources including tunnel conditions, balance measurements, extrapolation tolerances allowed in predicting coefficients (for trajectory data), and CTS positioning control. The maximum error in CTS position control was ± 0.05 in. (0.06 ft full scale) in translational settings, ± 0.15 deg for angular displacement settings in pitch and yaw, and ± 1.0 deg in roll. Extrapolation tolerances were ± 0.10 for each of the aerodynamic coefficients. Typical uncertainties in the full-scale position data resulting from balance precision limitations are presented in Table 3. These values are conservative in that they were determined by assuming that balance measurement errors accumulate as a bias uncertainty in the trajectory calculations. Uncertainties in the aerodynamic coefficients obtained during the flow-field surveys are also included in this table. All calculated coefficient uncertainties are based on a 95-percent confidence level. The uncertainty in determining the aircraft model angle of attack is estimated to be no larger than ± 0.10 deg.

4.0 RESULTS AND DISCUSSION

Selected aerodynamic free-stream data, aerodynamic loads (grid) data, and separation trajectory data are included in this report. The data included were chosen to show the basic aerodynamic characteristics of each store in the various configurations or to indicate the effect on the store of changing a particular parameter. The configurations for which data were acquired are shown in Fig. 8. Although only a portion of the total data obtained is presented, a complete summary of the test is included in Table 2. Model parameters used in the data calculations are detailed in Table 1.

4.1 TRAJECTORY DATA

Separation trajectory data were obtained on the GBU-8 and MK-82SE stores only. These data are presented in Figs. 9 and 10 in the flight-axis coordinate system with the origin at the carriage position of the respective store. Upon release, the GBU-8 exhibited slight pitch and yaw oscillations, the magnitude of which varied with Mach number. The MK-82SE exhibited a much larger initial pitch rate. At Mach numbers of 0.9 and 0.95, the initial pitch motion was so rapid that CTS travel limits were encountered before the store reached the maximum nose-down pitch attitude.

4.2 FREE-STREAM DATA

Summaries of the aerodynamic coefficients obtained in the free stream with the three store models are included in Fig. 11. The data are presented as store body-axis coefficients and were acquired with the F-16 aircraft model removed from the wind tunnel.

4.3 AERODYNAMIC LOADS SURVEYS

Aerodynamic body-axis coefficients obtained from the surveys made in the influence of the F-16 flow field are presented in Figs. 12 through 19 for the BLU-27B/B, in Figs. 20 through 23 for the GBU-8, and in Figs. 24 through 46 for the MK-82SE. The data are plotted as functions of the pylon-axis spatial coordinates at which the data were acquired. The indicated aircraft configurations are defined in Fig. 8. All surveys were initiated with the store in the carriage position at the pylon and rack location given in the figure heading. Rack stations are numbered as shown in Fig. 7.

In general, flow-field effects on the aerodynamic coefficients of the BLU-27B/B had dissipated at a vertical separation of 16 ft or greater, regardless of the aircraft configuration. The actual distance at which the effects were no longer significant did vary slightly with configuration and with the aerodynamic coefficient under consideration.

Aircraft flow-field effects noted on the GBU-8 were considerably more pronounced than those on the BLU-27B/B and persisted to distances beyond 18 ft (especially at supersonic Mach numbers). The variation in coefficients resulting from the addition of a 370-gal fuel tank to the inboard pylon was most evident at $M_\infty = 1.2$ and also continued beyond 18 ft vertically from the aircraft.

Data acquired with the MK-82SE indicated that the aerodynamic coefficients were approaching free-stream values at separations of 16 ft when the aircraft angle of attack was 6 deg or less. At an angle of attack of 10 deg, the effect of the F-16 flow field was still evident at 18 ft, which was the maximum vertical separation obtained with the MK-82SE.

The change in aerodynamic coefficients caused by deflecting the F-16 wing-leading-edge flaps 4 deg and 15 deg was investigated using the MK-82SE. The variation caused by placing the flaps in the 4-deg position was very small and had dissipated within 1 ft of the carriage position. The effects with the 15-deg flap deflection were of greater magnitude and extended beyond 14 ft separation in some instances. The actual distance at which the flap effects ceased to be significant was configuration dependent.

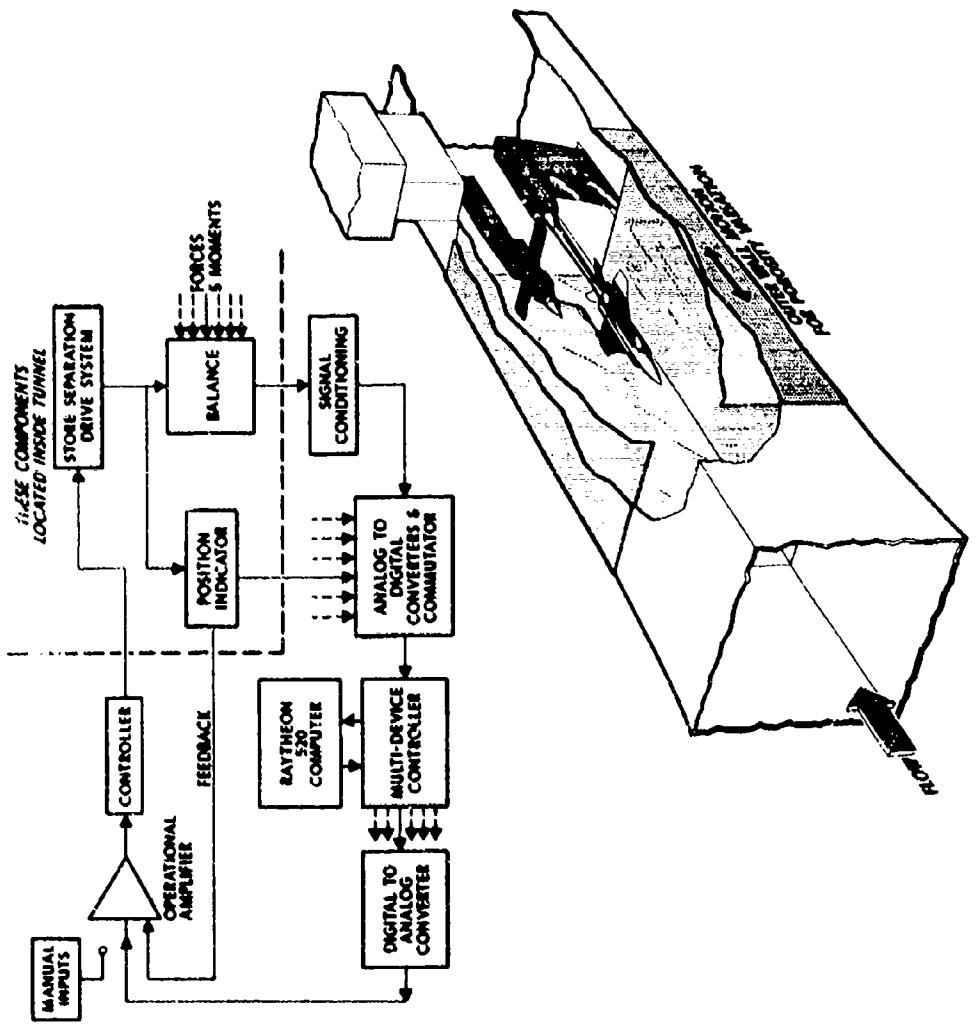


Figure 1. Isometric drawing of a typical store separation installation and a block diagram of the computer control loop.

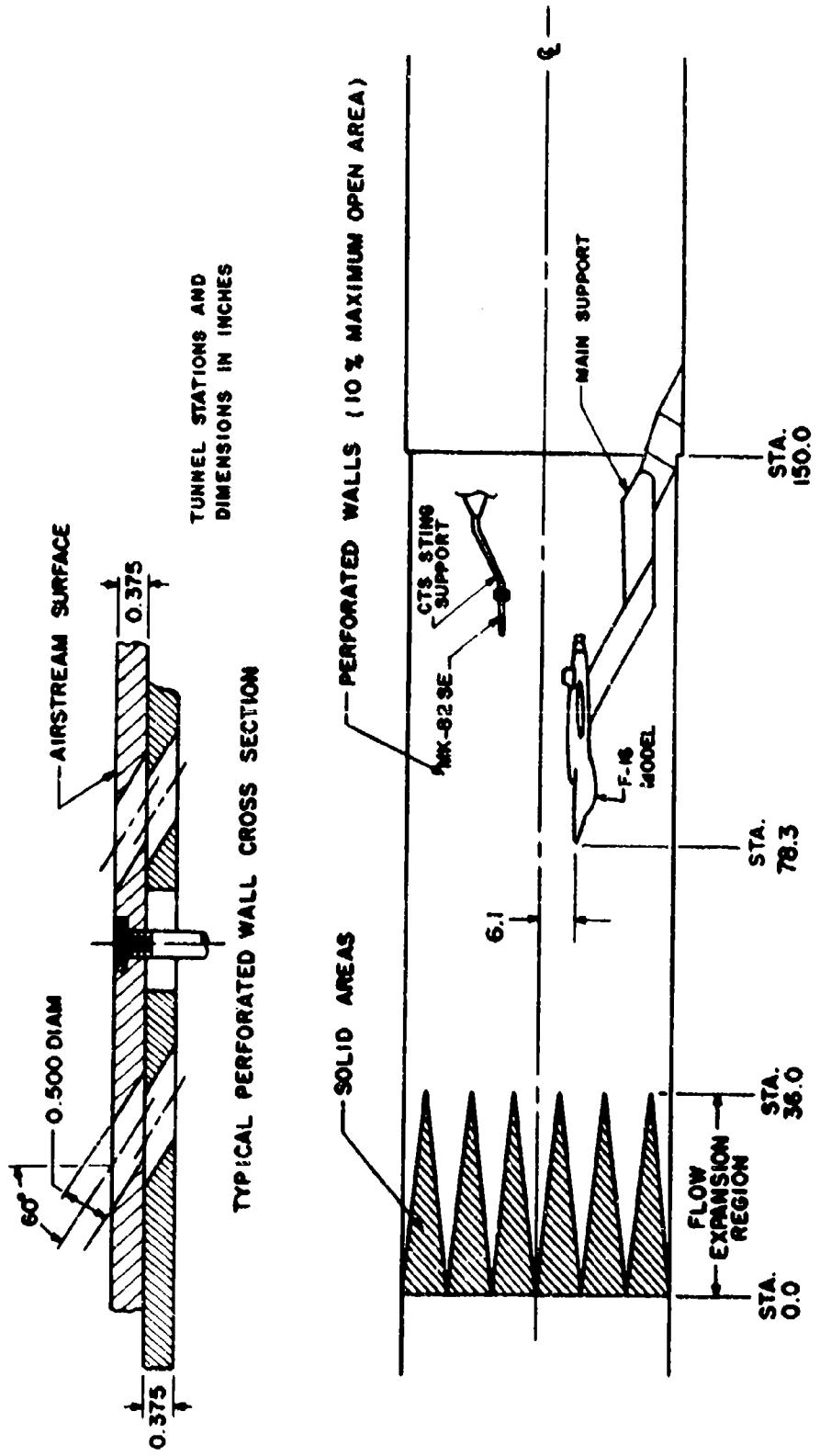


Figure 2. Schematics of test installations.
a. MK-82SE

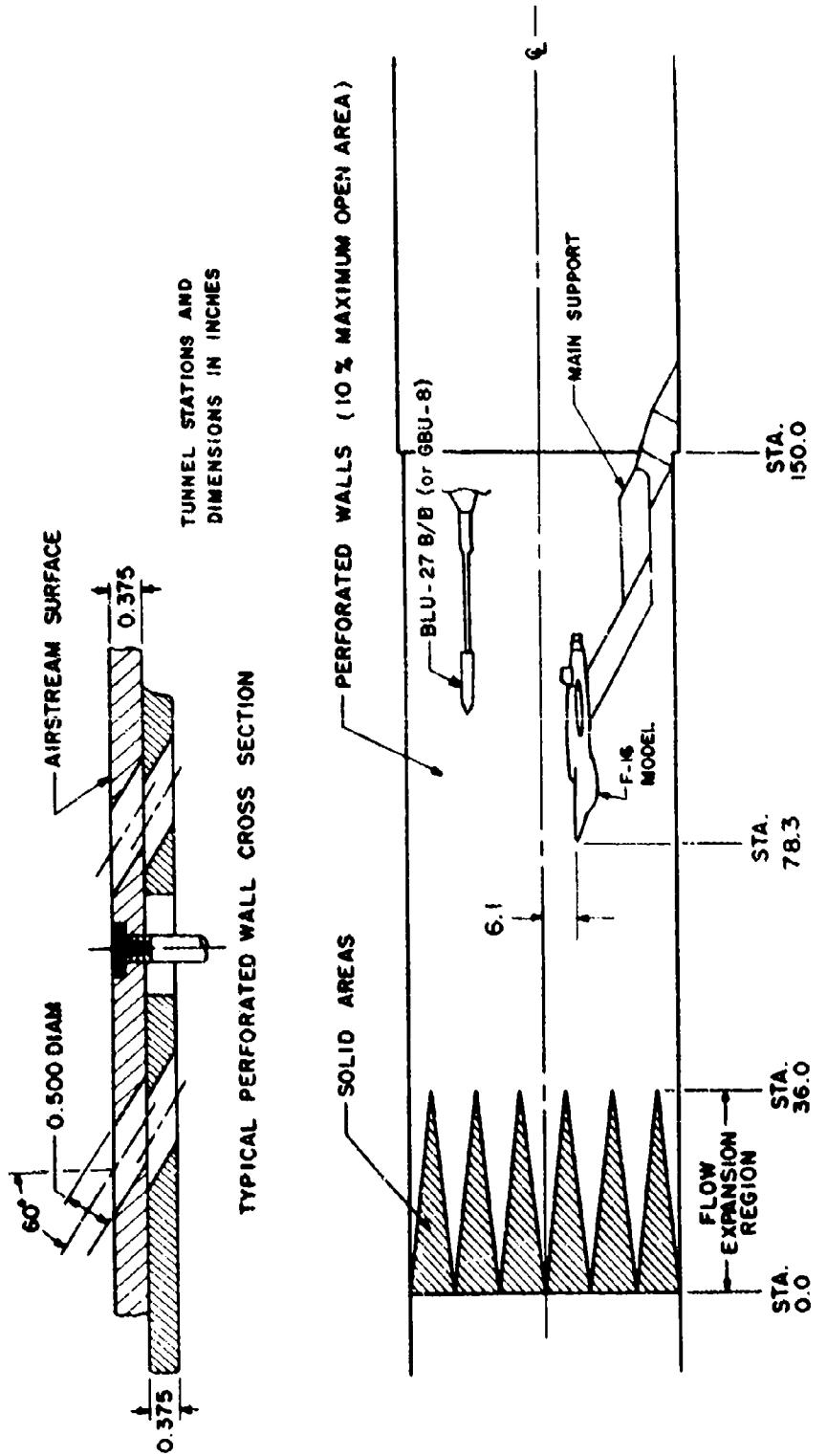


Figure 2. Concluded.

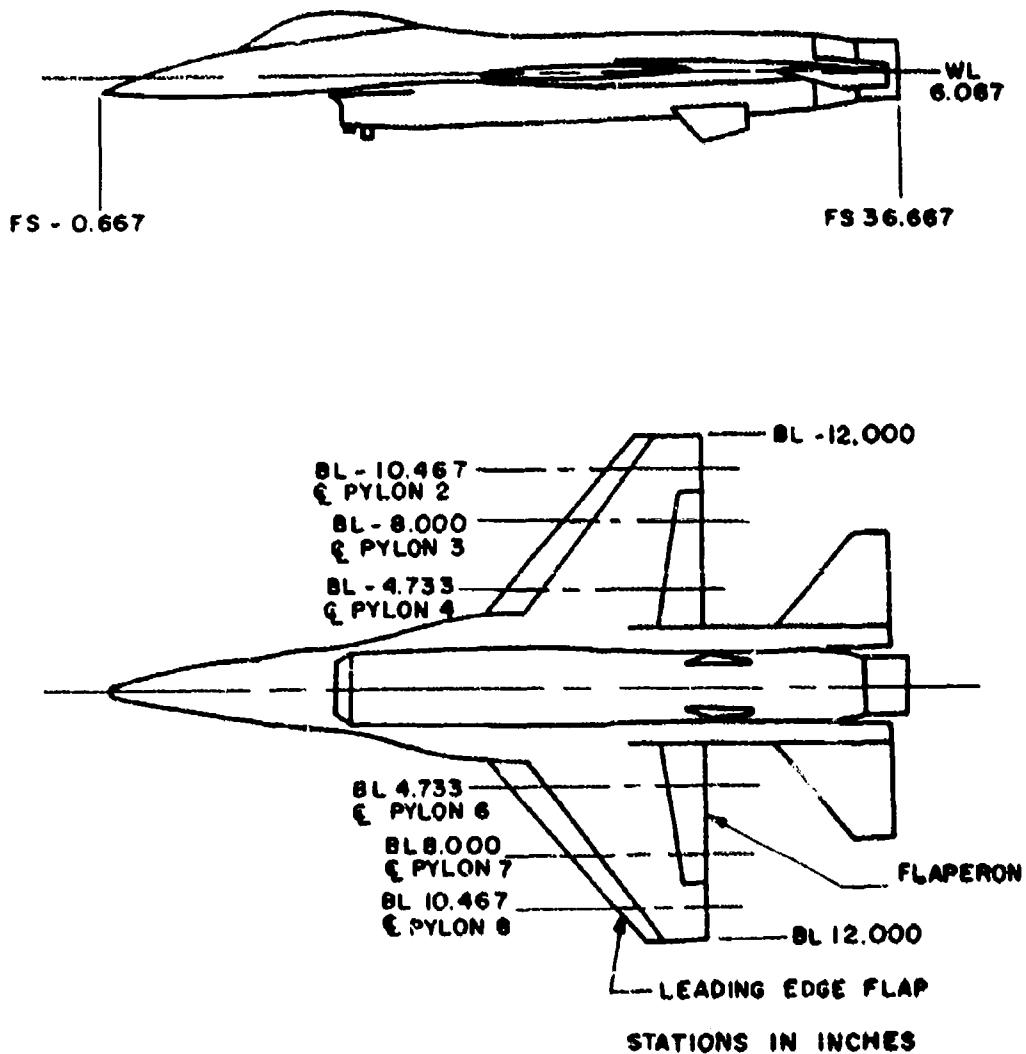
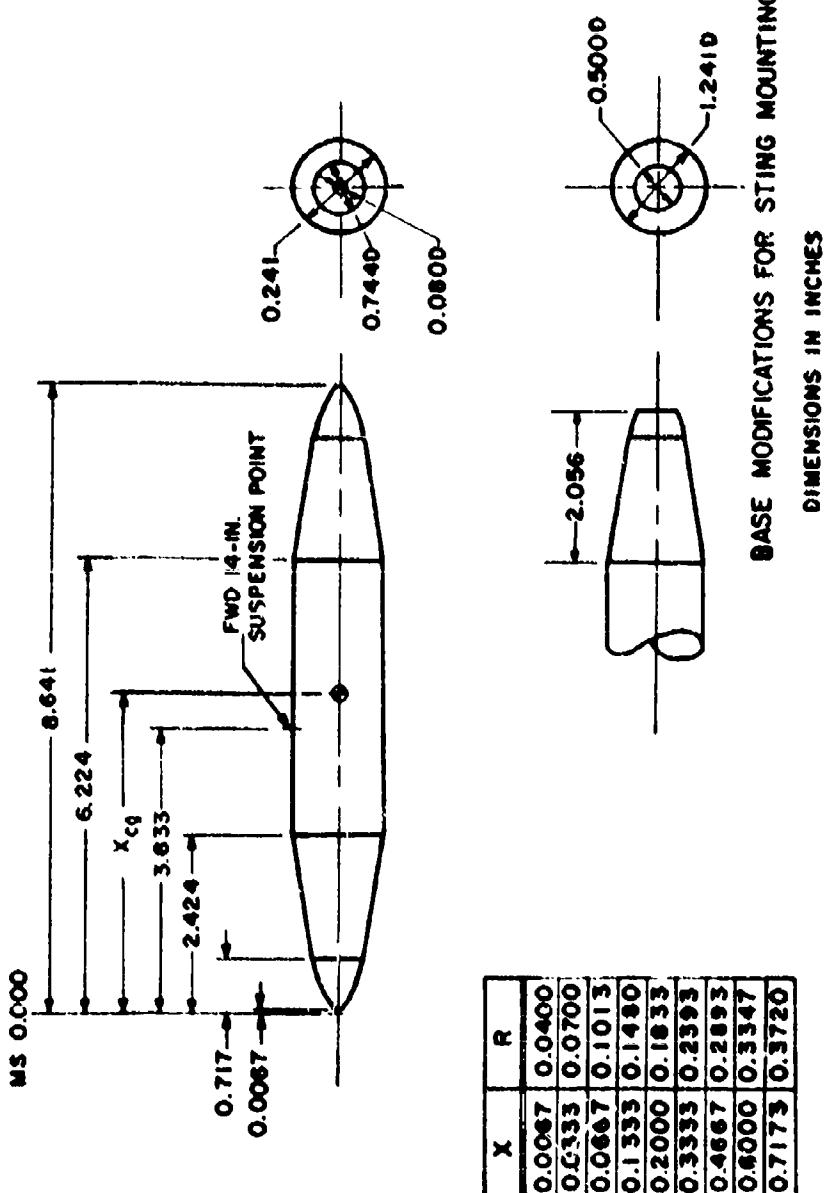
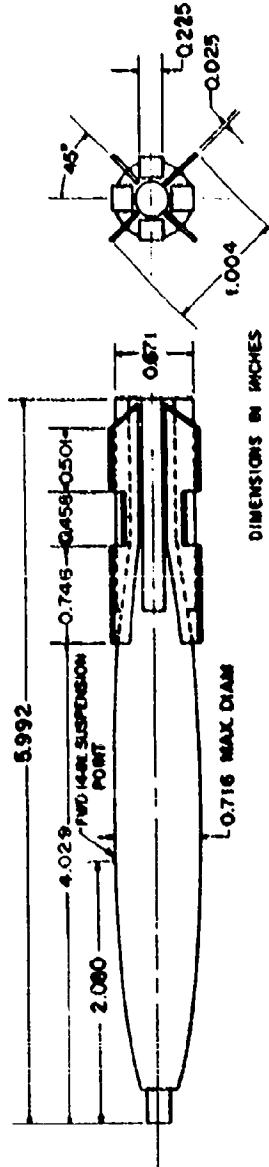


Figure 3. Dimensional sketch of the F-16 parent model.



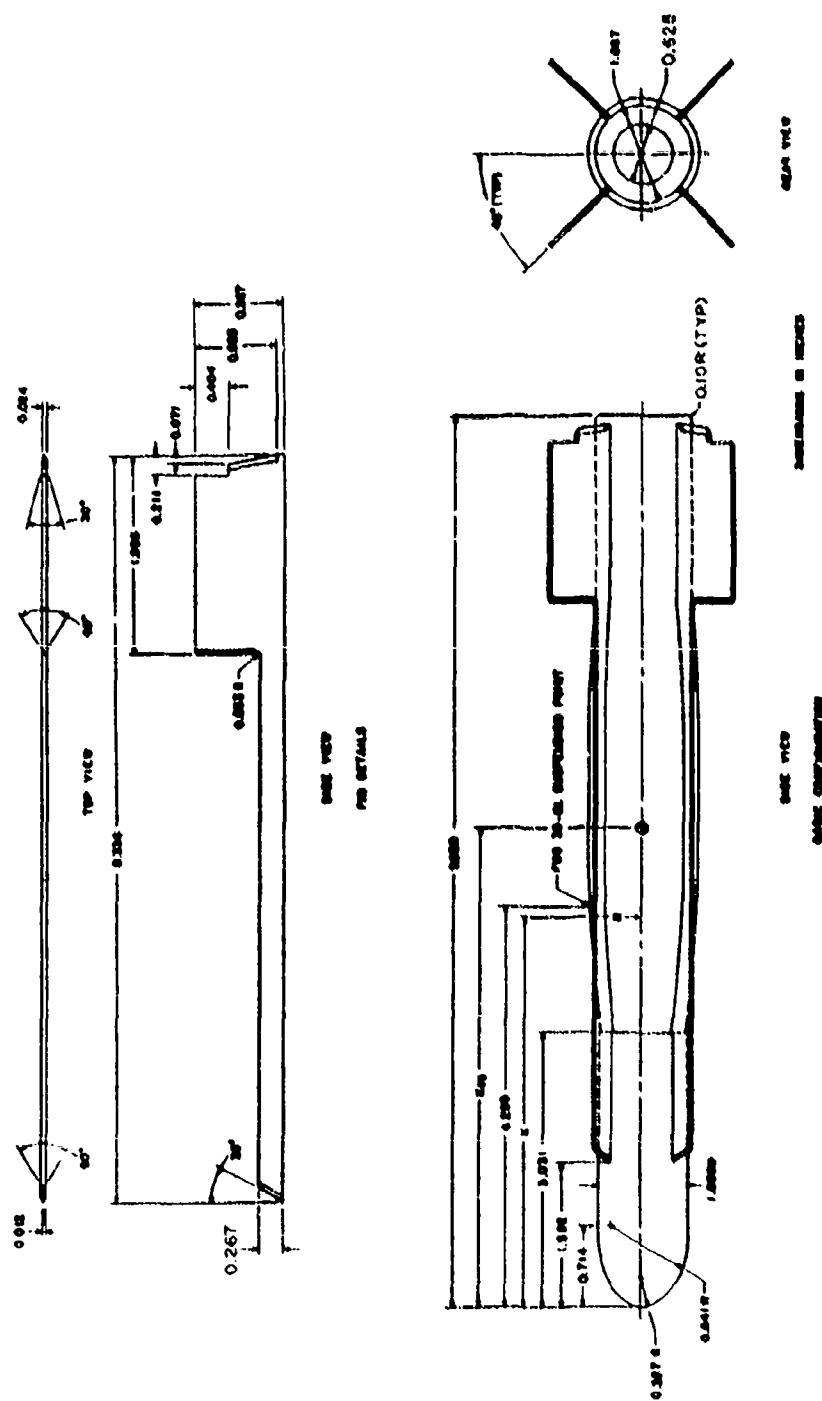
a. BLU-27/B/B
Figure 4. Dimensional sketches of the store models.



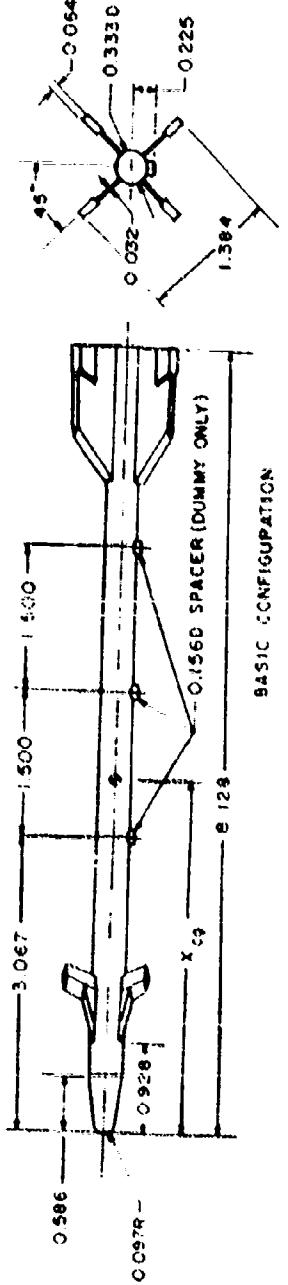
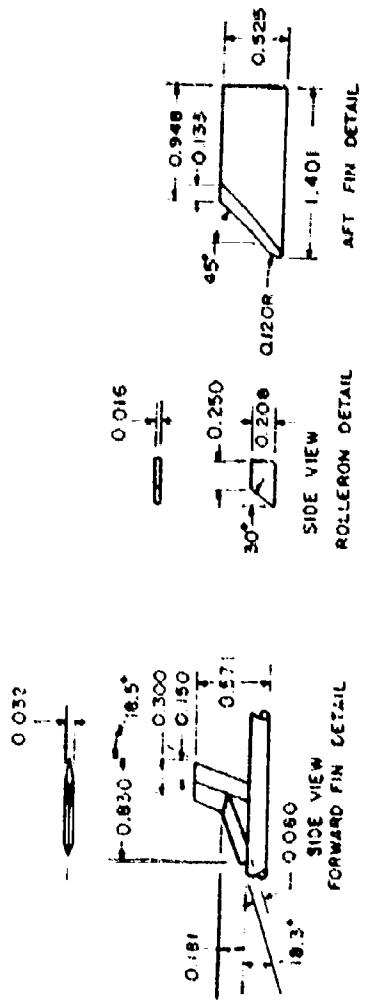
b. MK-82SE metric model

BODY GEOMETRY

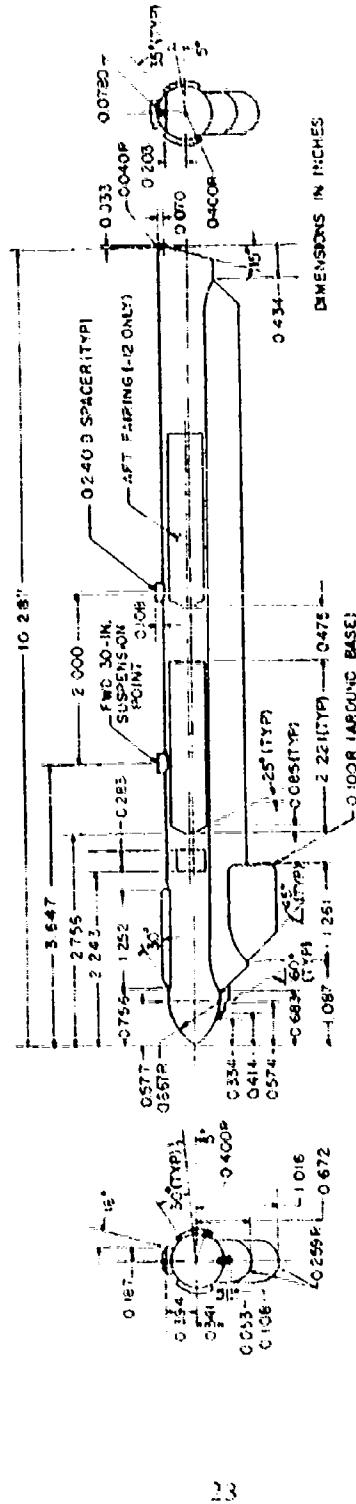
STA	DIAM
0	0
0.080	0.096
0.240	0.224
0.587	0.416
1.068	0.566
1.611	0.666
2.157	0.716
CONST DIAM	
3.045	0.716
3.592	0.692
4.054	0.630
CONST SLOPE	
5.501	0.300
CONST DIAM	
6.156	0.300



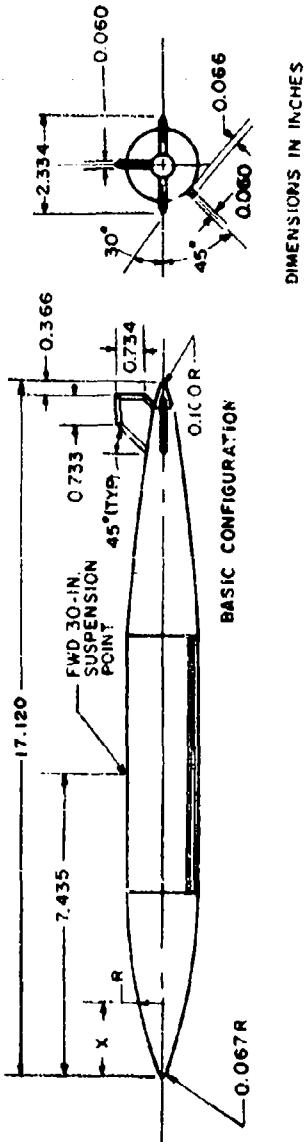
d. GBU-8 metric model



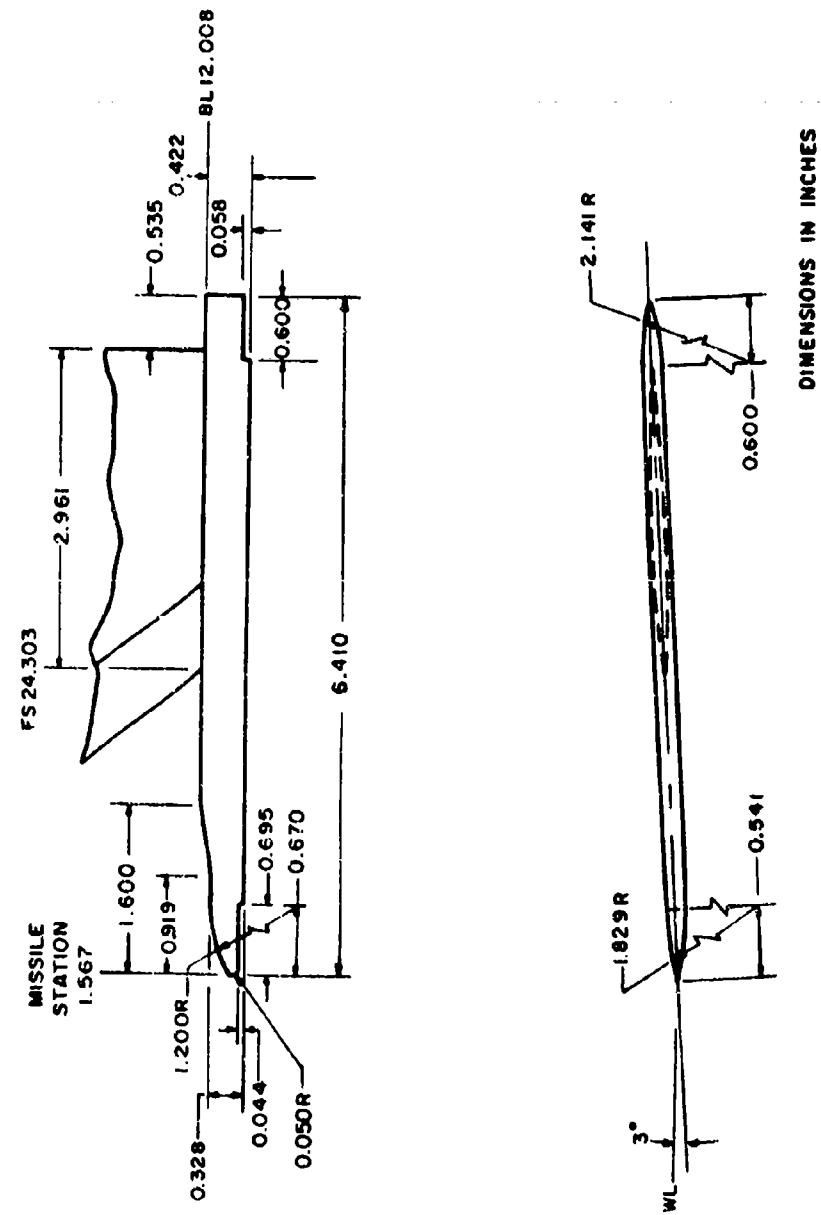
- AIM-9J dummy model
- Figure 4. Continued.



X, in.	R, in.	X, in.	R, in.
0	0	4.520	0.983
0.053	0.038	4.520	0.577
0.120	0.100	10.830	0.561
0.186	0.131	C.863	0.565
0.320	0.168	CONST	0.565
0.453	0.242	CONST	0.565
0.587	0.291	16.520	0.242
0.720	0.336	SLOPE	0.242
0.854	0.377	12.270	0.757
0.951	0.416	12.336	0.752
		12.670	0.724
		16.787	0.192
		16.920	0.156
		17.054	0.097
		17.120	0
		13.337	0.653
		13.387	0.799
		13.670	0.616
			0

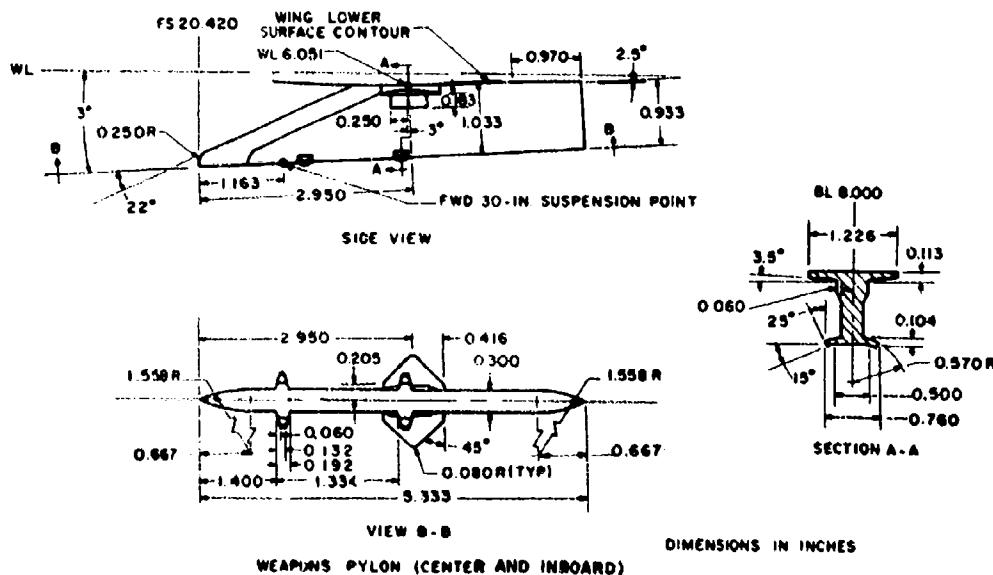
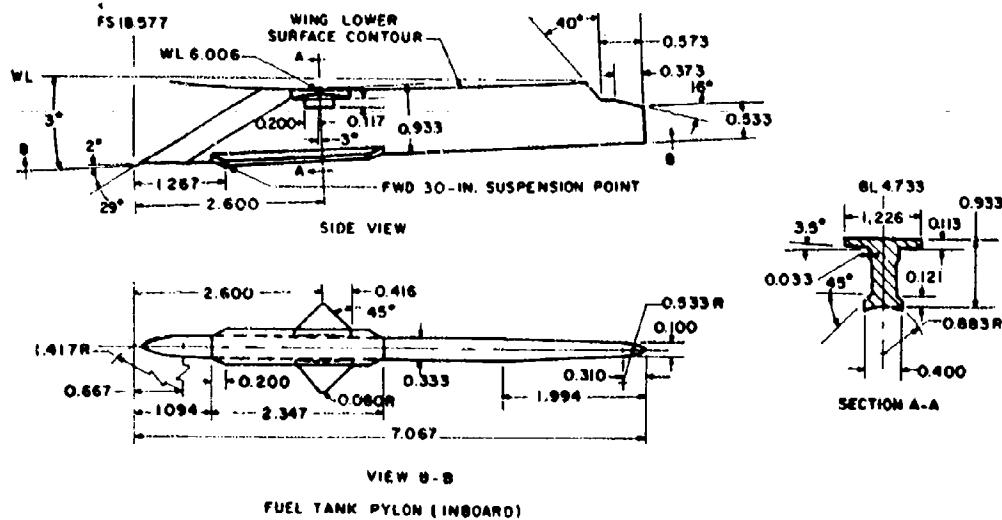


9. 370-gal fuel tank dummy model
Figure 4. Concluded.

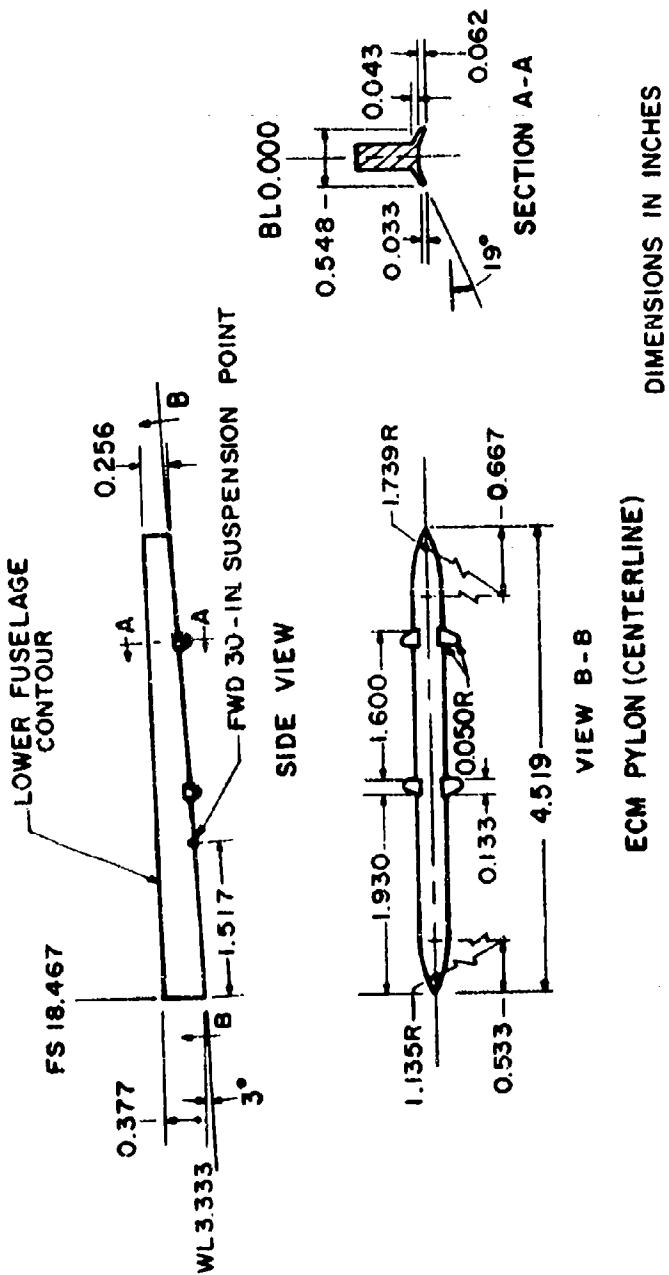


AIM-9J wing tip launcher

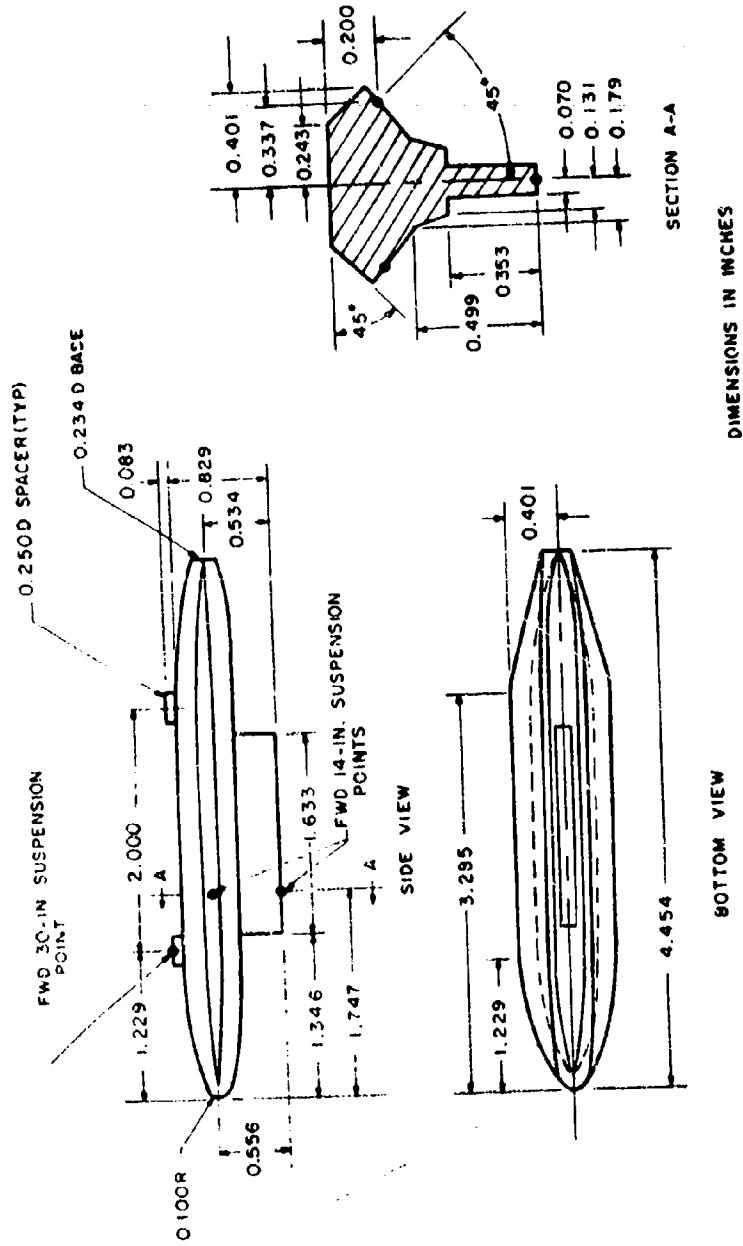
Figure 5. F-16 model pylons and racks.



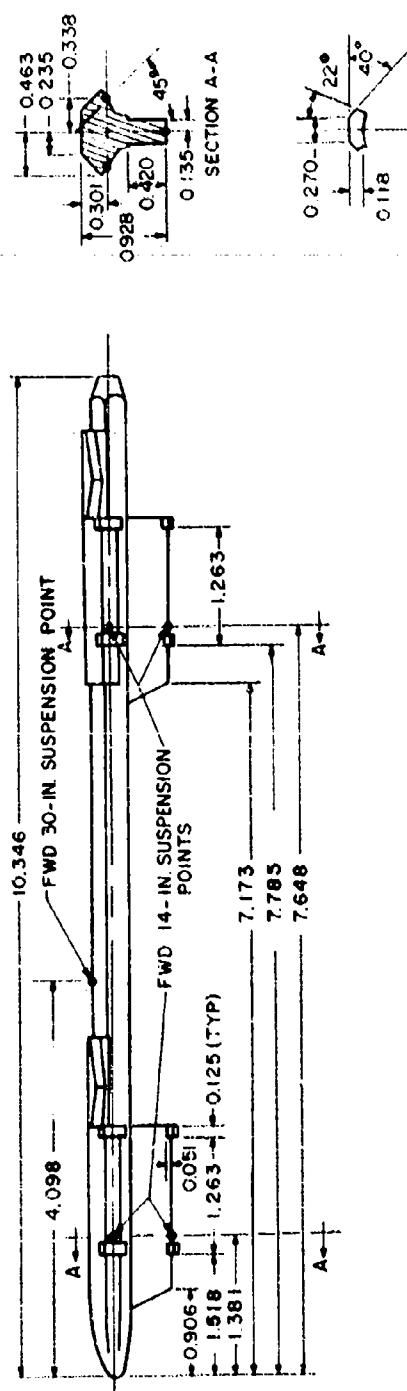
b. Midwing and inboard pylons
Figure 5. Continued.



c. Centerline ECM pylon
Figure 5. Continued.



d. Triple ejection rack
Figure 5. Continued.

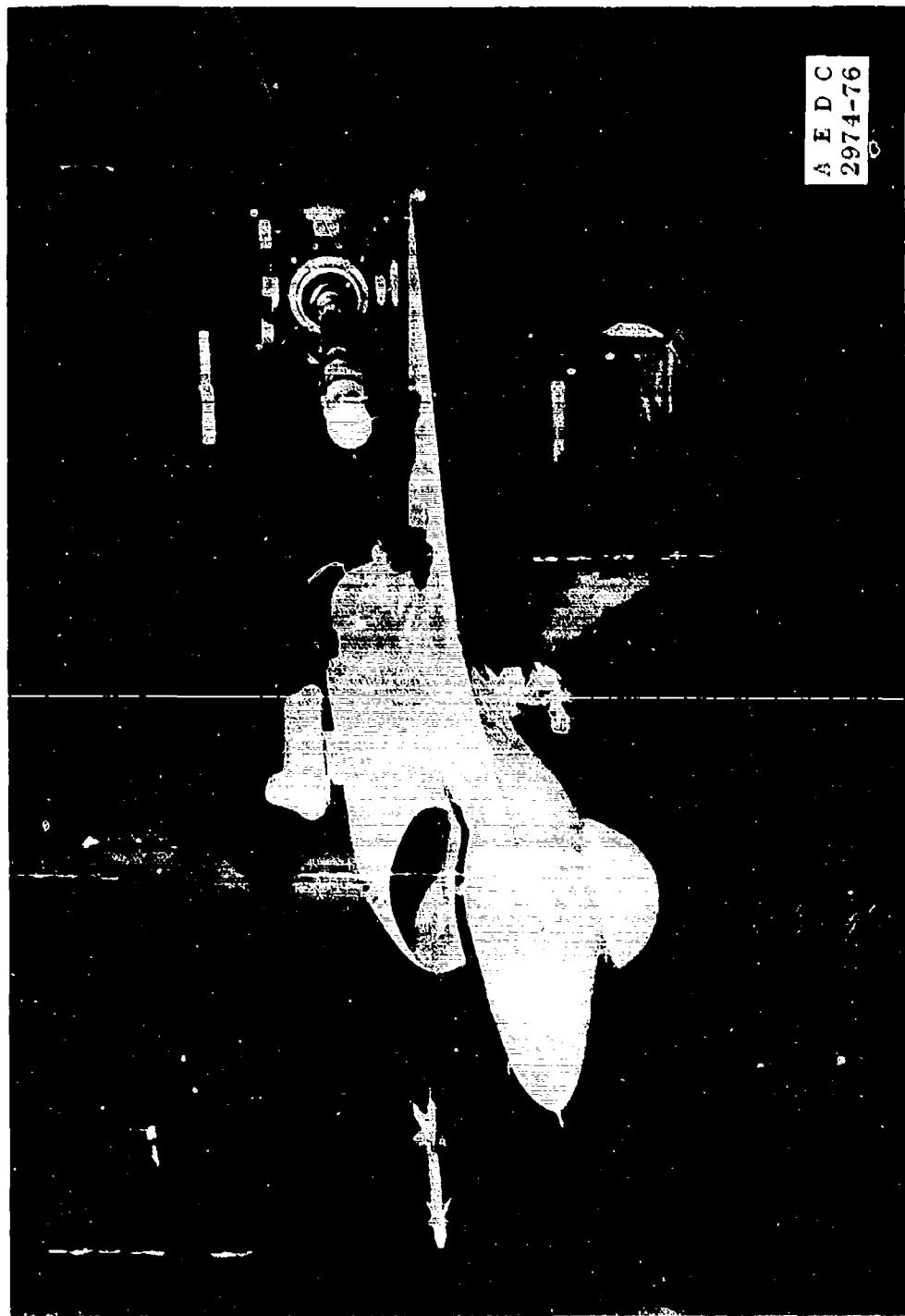


DIMENSIONS IN INCHES

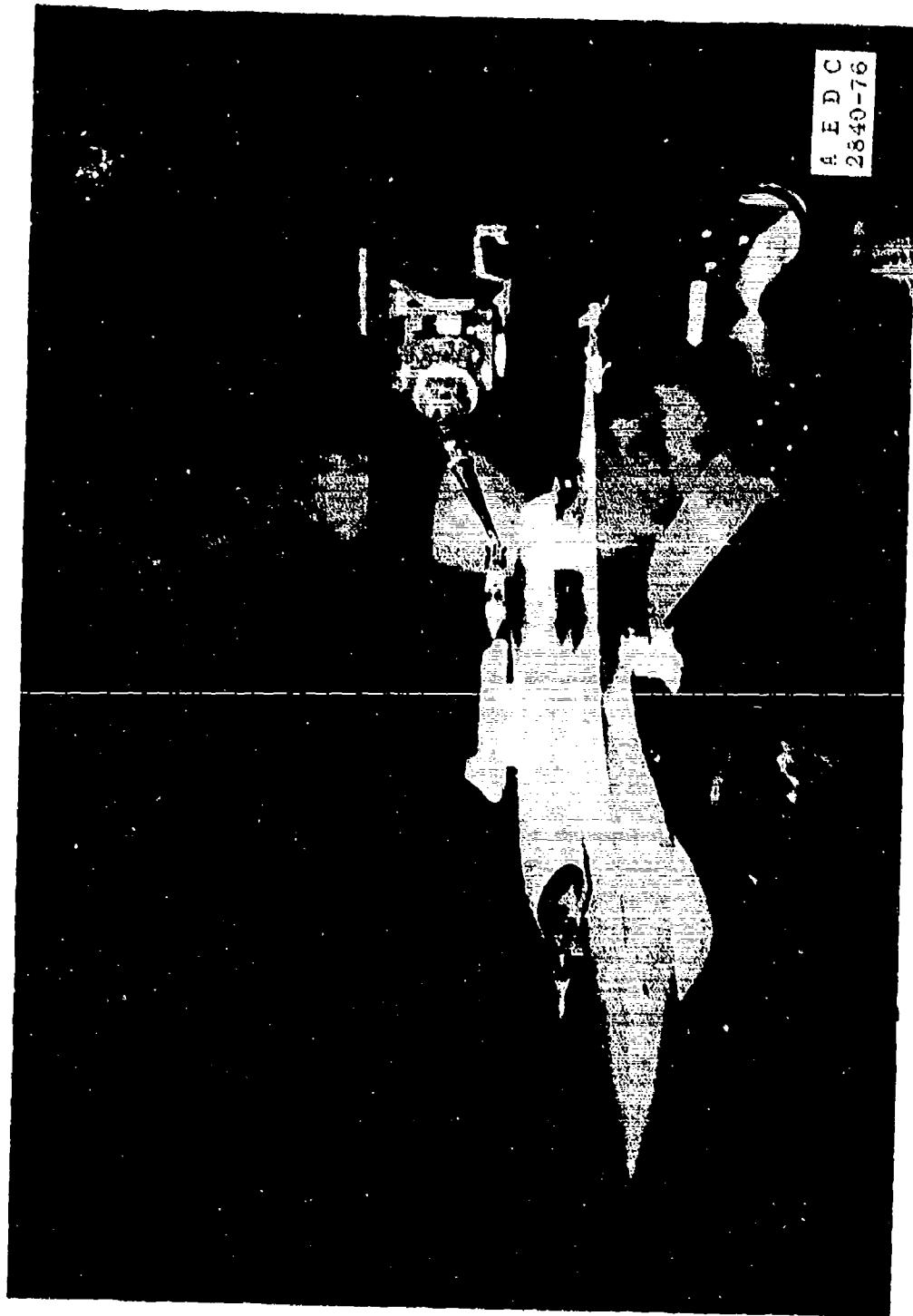
- Multiple ejection rack
Figure 5. Concluded.



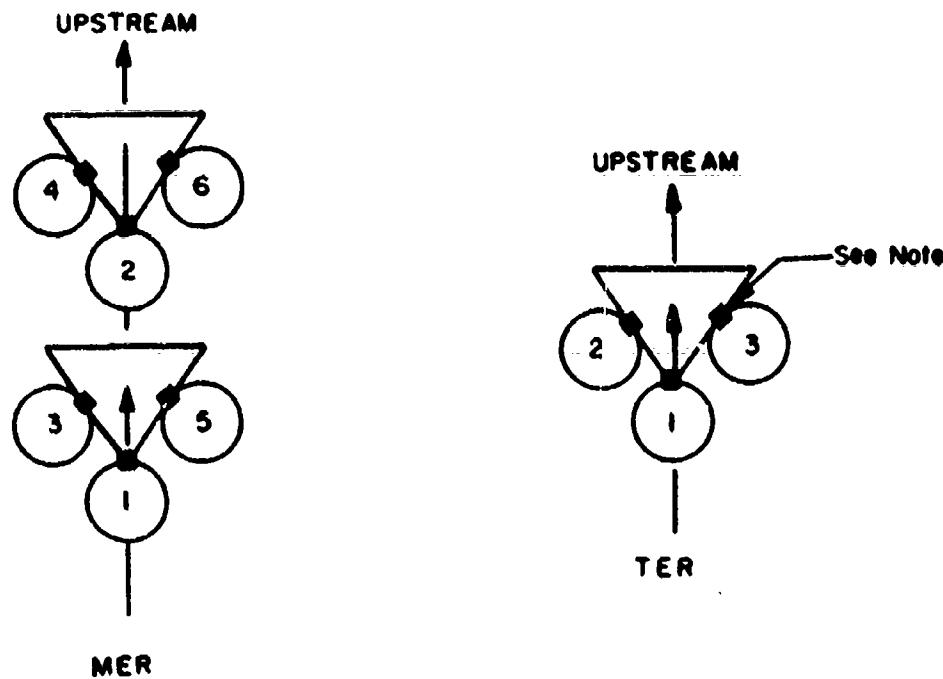
a. BLU-27B/B, configuration 4
Figure 6. Installation photographs.



b. GBU-8, configuration 7
Figure 6, Continued.



c. MK-82SE, configuration 17
Figure 6. Concluded.



NOTE: The square indicates the orientation of the suspension lugs

TYPE RACK	STATION	ROLL ORIENTATION, deg
MER	1	0
	2	0
	3	45
	4	45
	5	-45
	6	-45
TER	1	0
	2	45
	3	-45

Figure 7. Store orientation.

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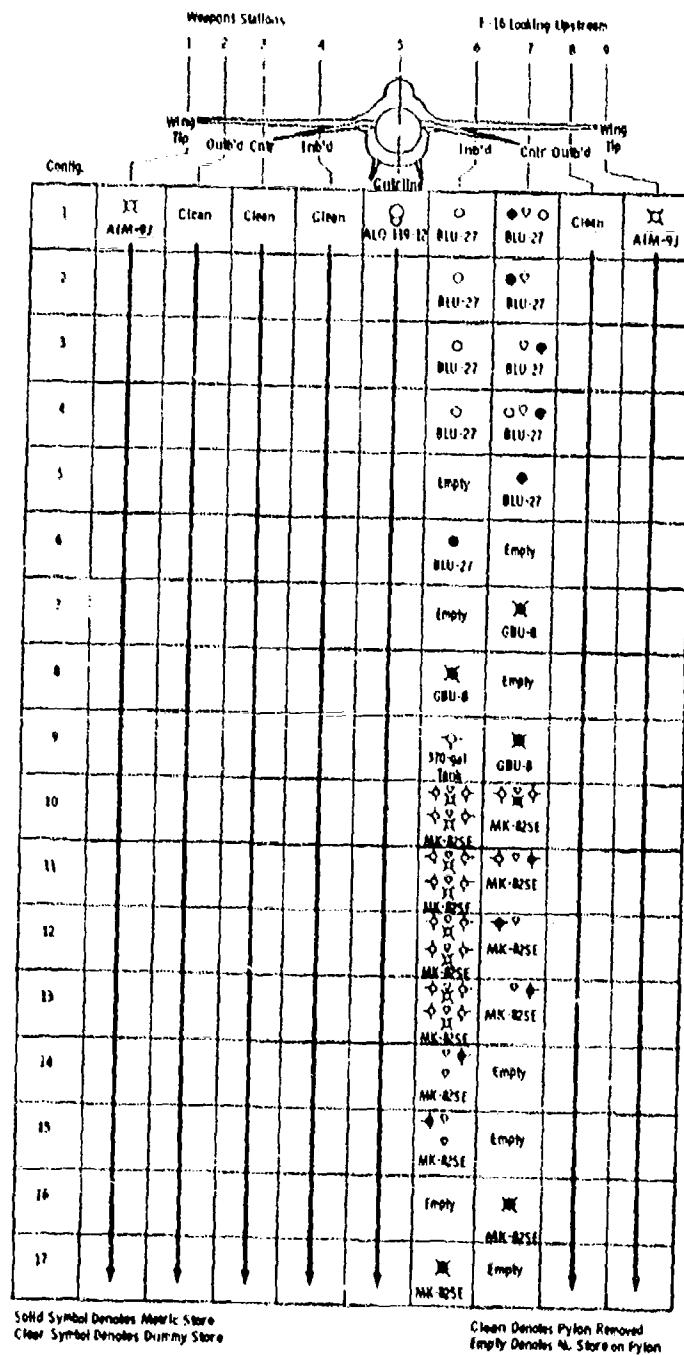
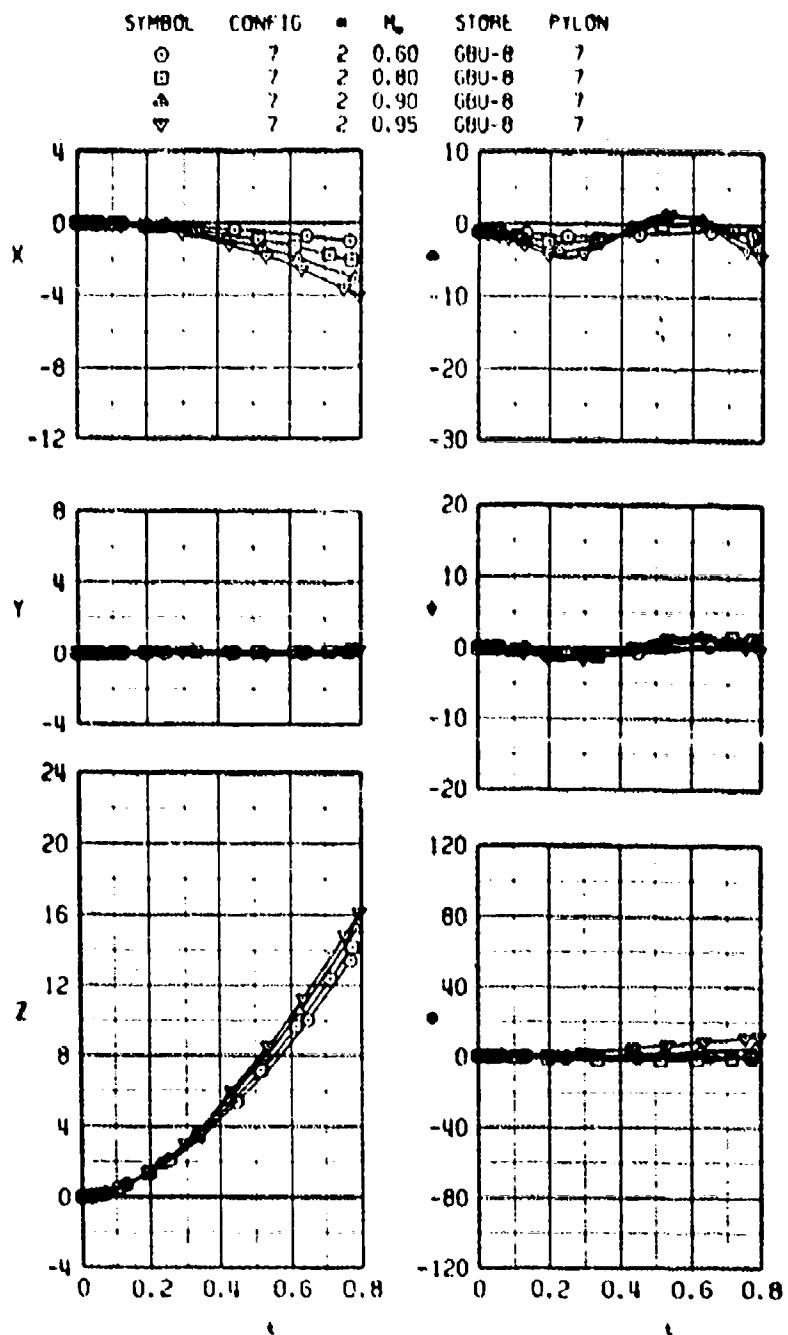
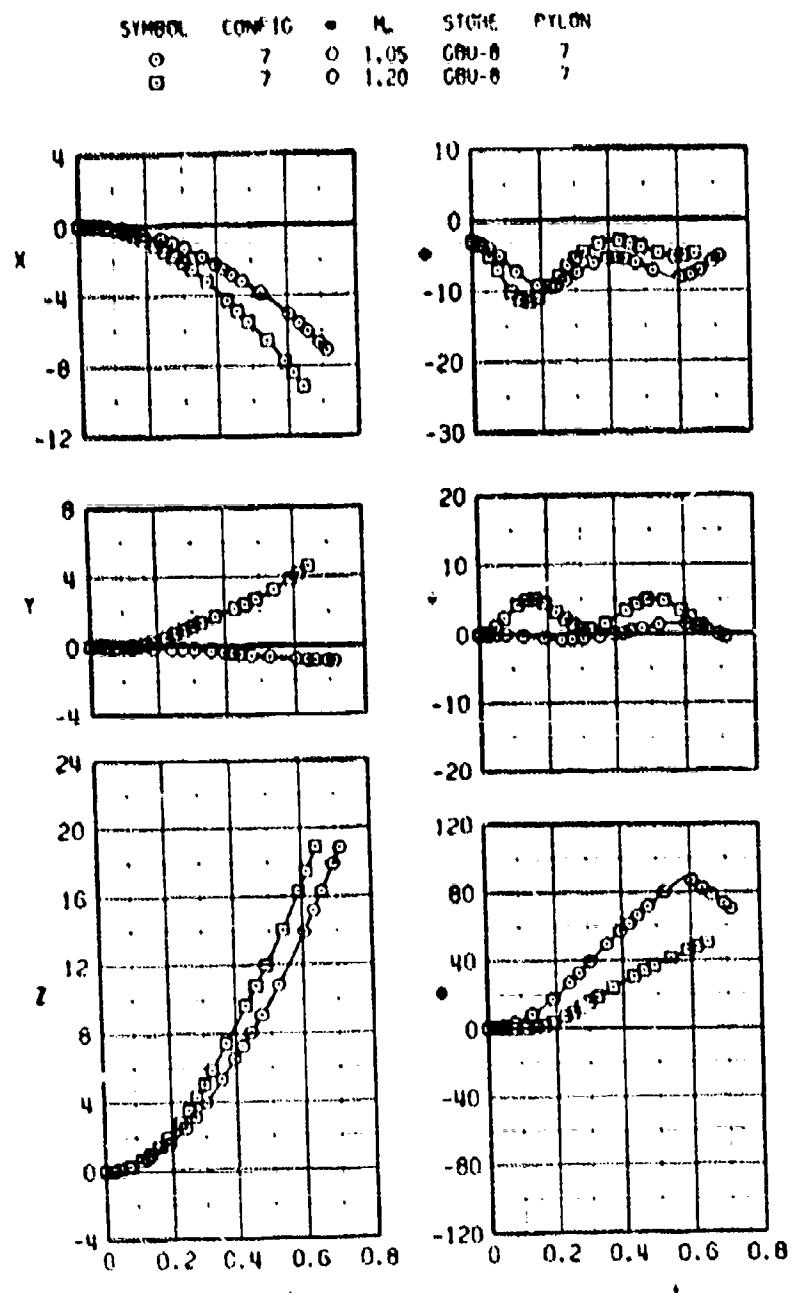


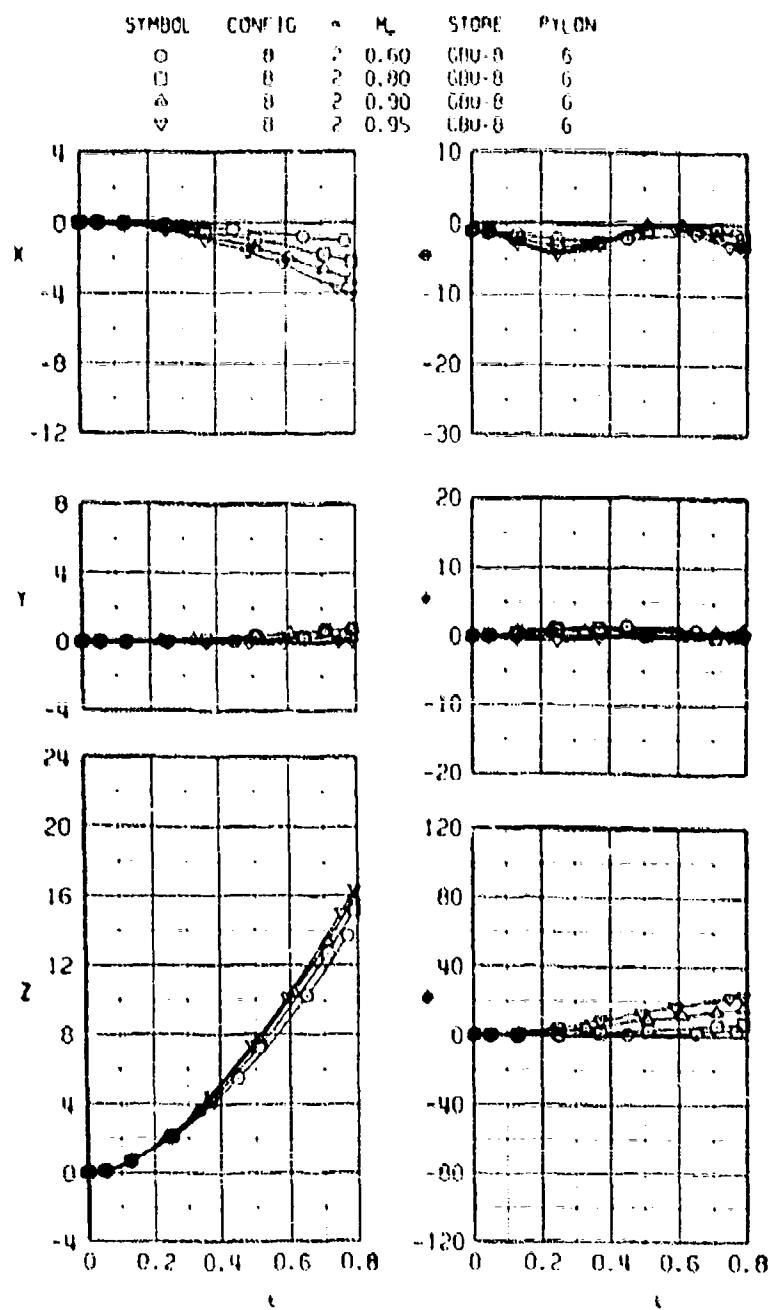
Figure 8. Configuration identification.



a. Configuration 7, $M_\infty = 0.6$ to 0.95
Figure 9. Trajectories obtained with the GBU-8.



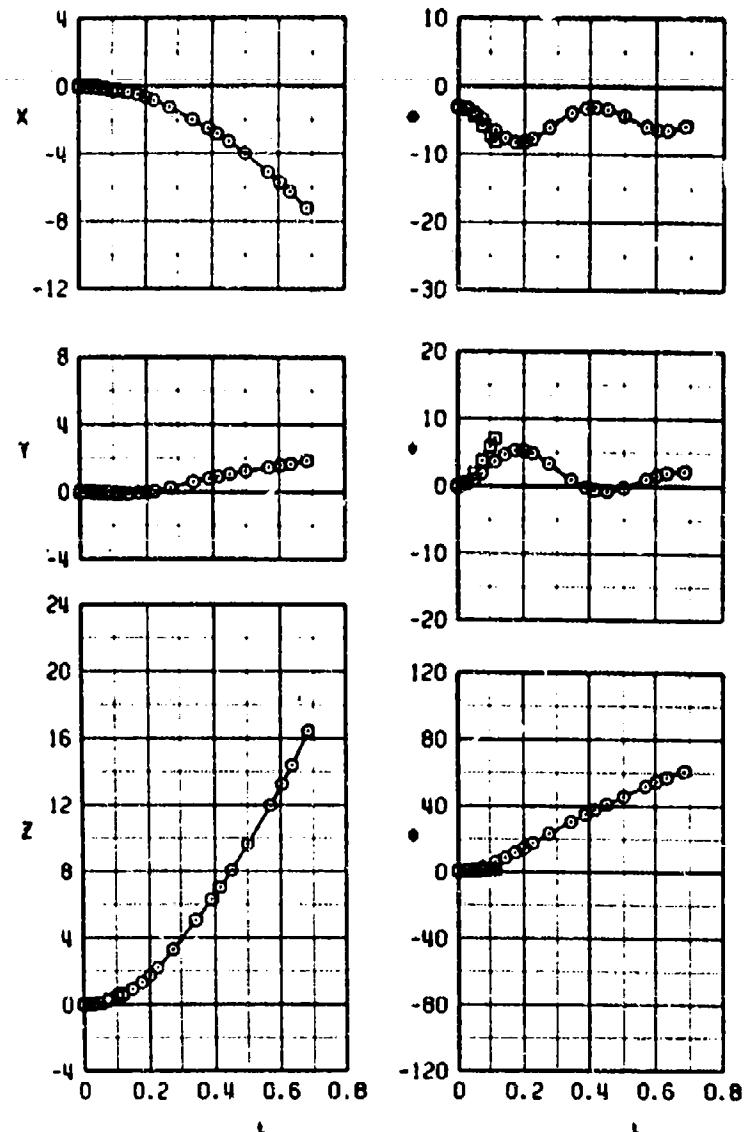
b. Configuration 7, $M_\infty = 1.05$ and 1.20
Figure 9. Continued.



c. Configuration 8, $M_\infty = 0.6$ to 0.95
Figure 9. Continued.

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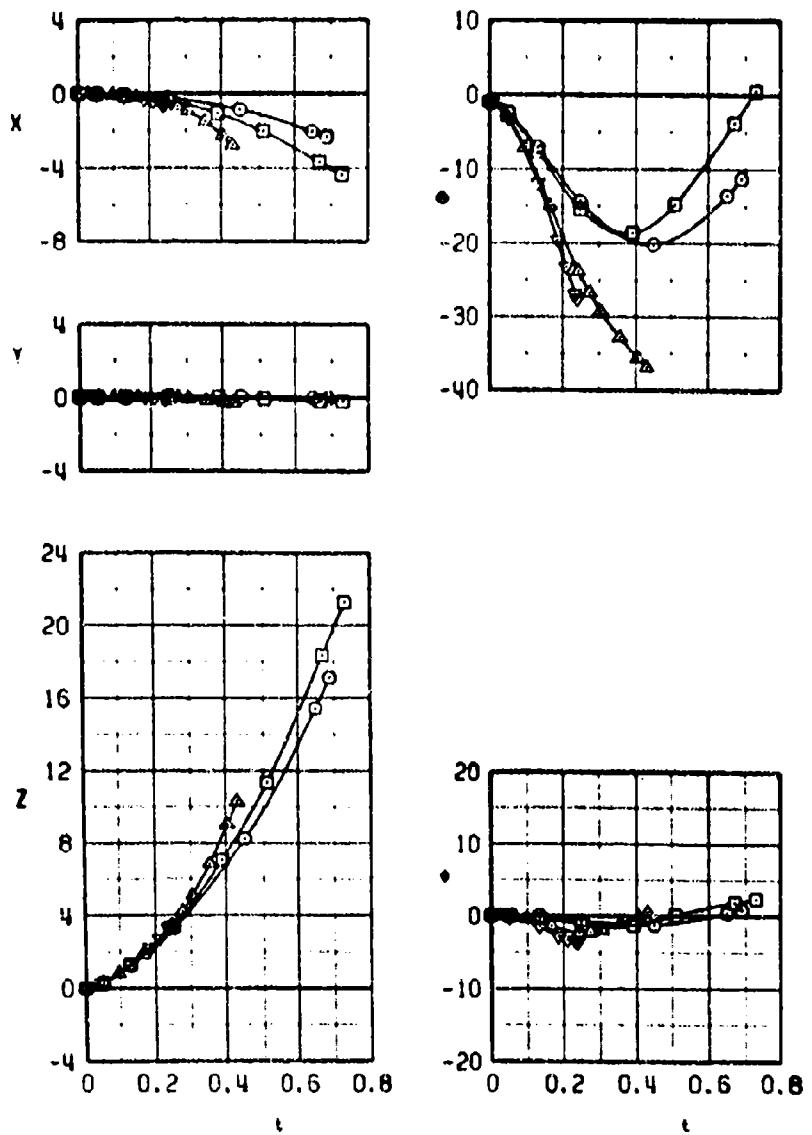
SYMBOL	CONFIG	M_∞	STORE	PYLON
○	8	0	1.05	GBU-8
□	8	0	1.20	GBU-8



d. Configuration 8, $M_\infty = 1.05$ and 1.20

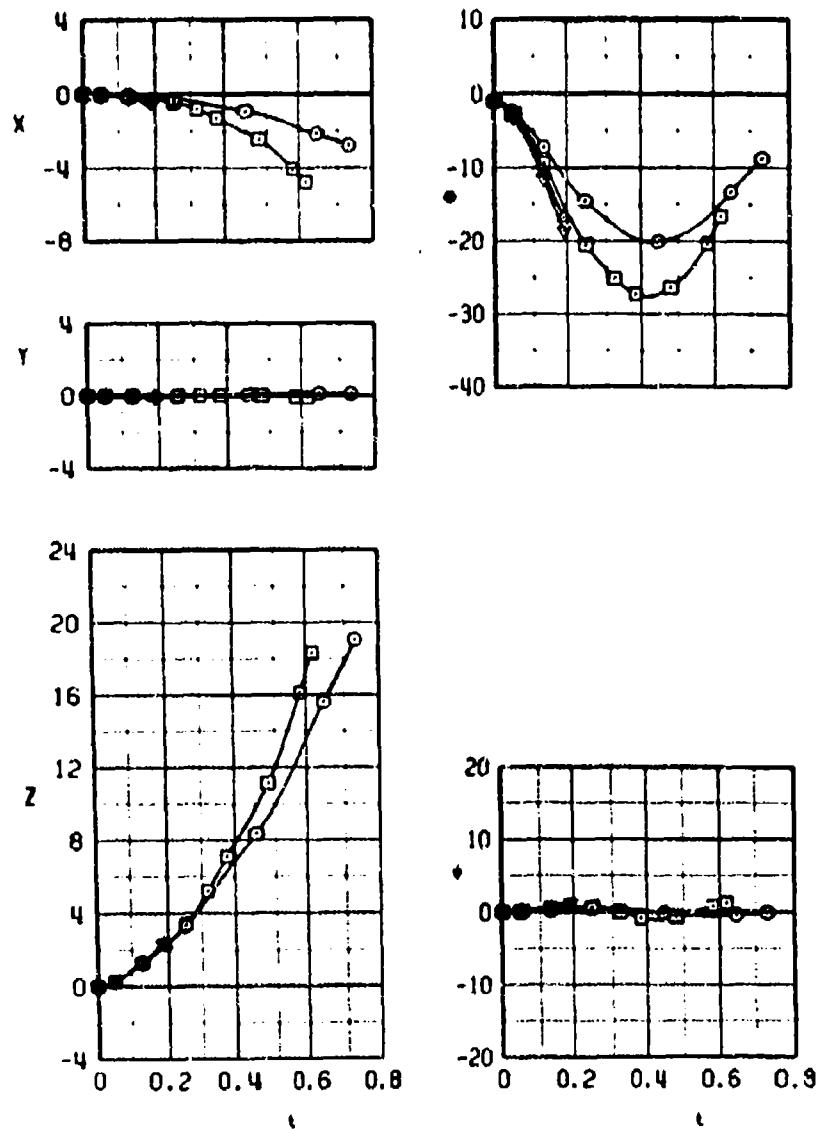
Figure 9. Concluded.

SYMBOL	CONFIG	α	M_∞	STORE	PYLON
O	16	2	0.60	MK-82SE	?
□	16	2	0.80	MK-82SE	?
△	16	2	0.90	MK-82SE	?
▽	16	2	0.95	MK-82SE	?

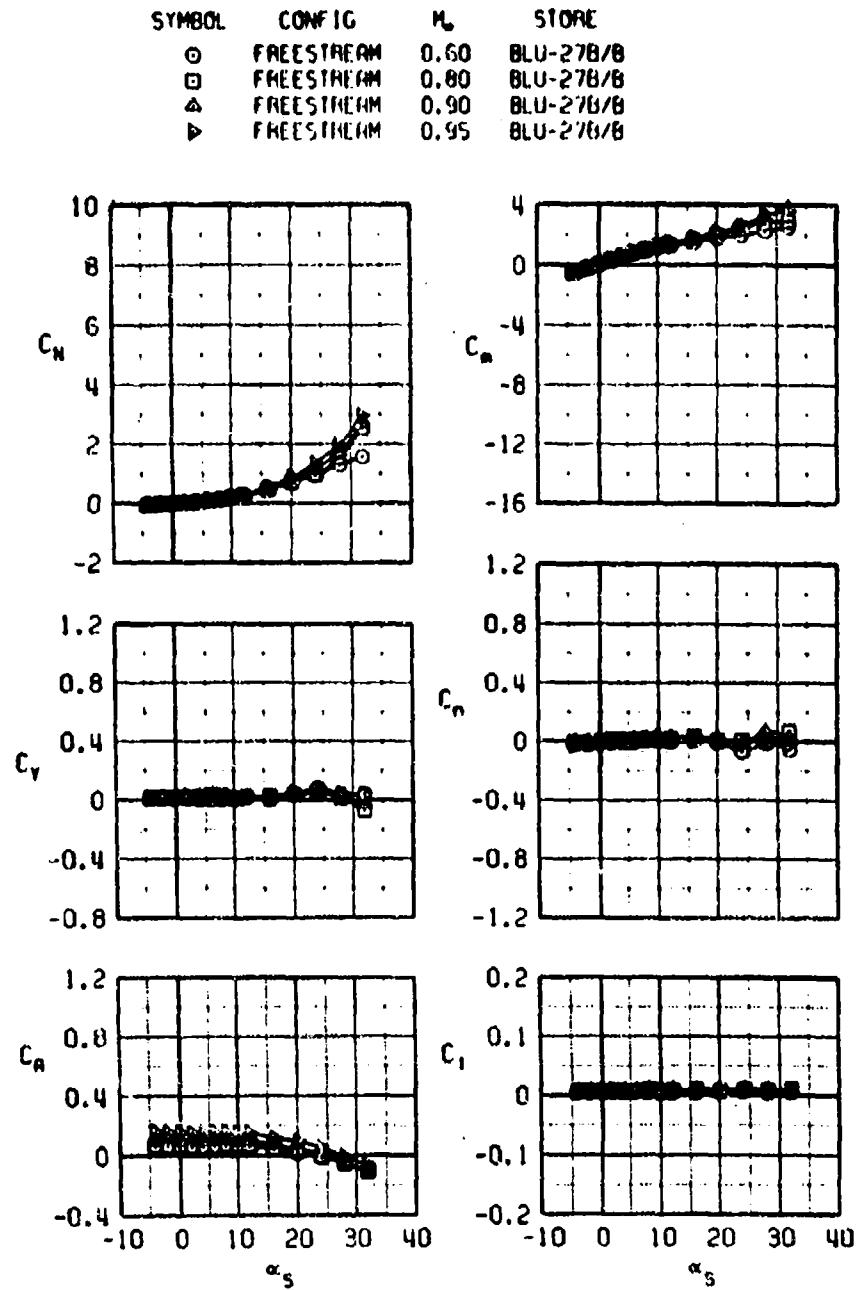


a. Configuration 16
Figure 10. Trajectories obtained with the MK-82SE.

SYMBOL	CONFIG	*	M _∞	STORE	PYLON
○	17	2	0.60	MK-82SE	6
□	17	2	0.80	MK-82SE	6
△	17	2	0.90	MK-82SE	6
▽	17	2	0.95	MK-82SE	6



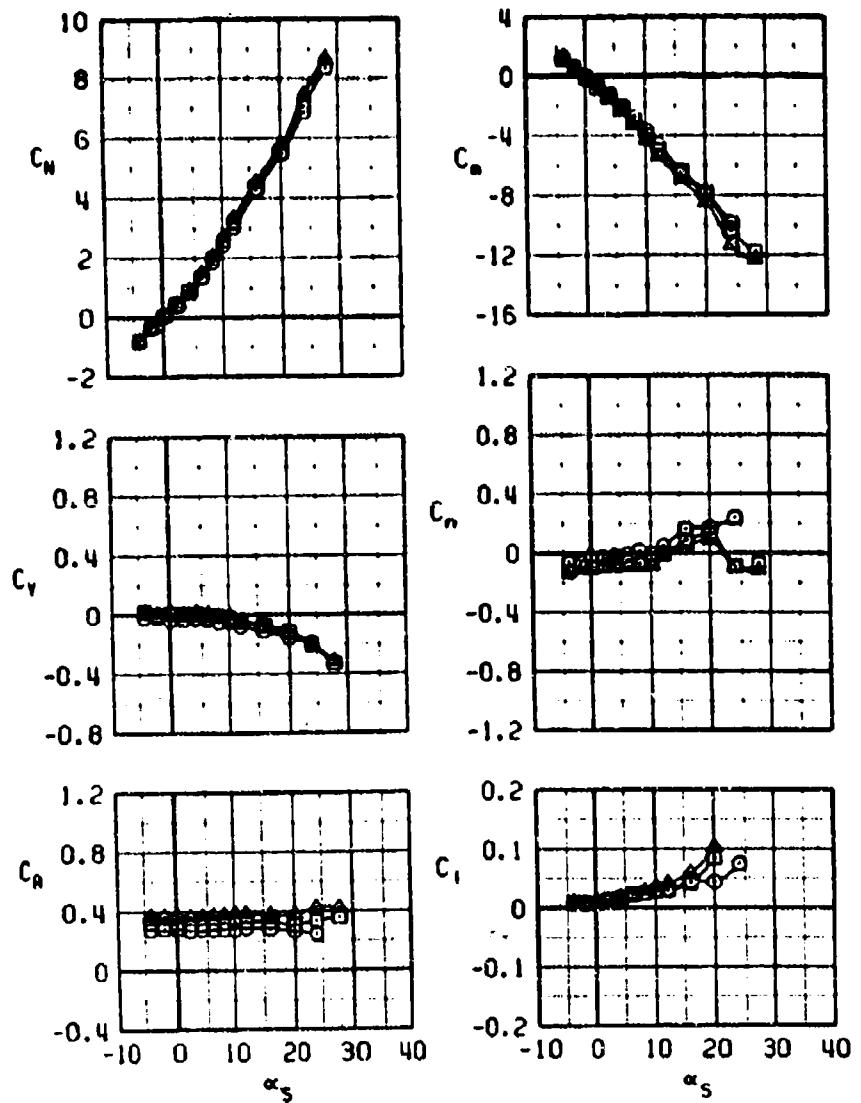
b. Configuration 17
Figure 10. Concluded.



a. BLU-27B/B

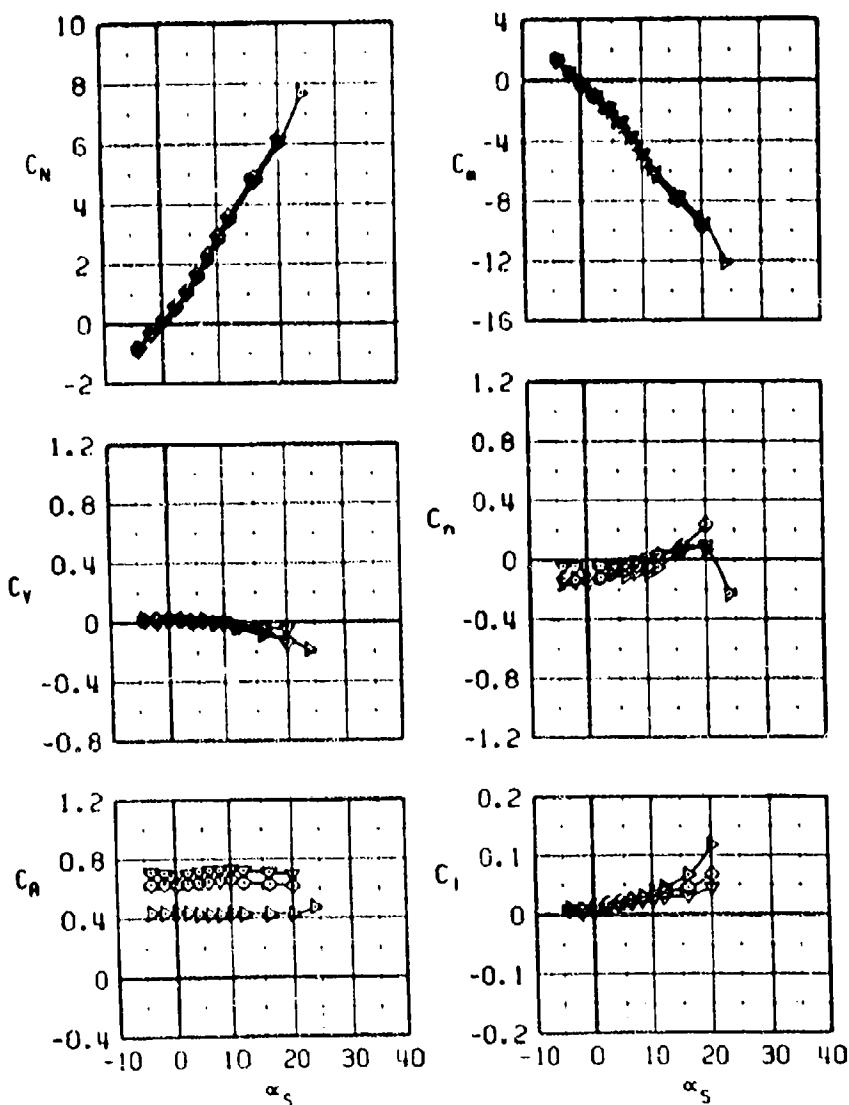
Figure 11. Free-stream aerodynamic coefficients.

SYMBOL	CONFIG	M_∞	STORE
○	FREESTREAM	0.60	GBU-8
□	FREESTREAM	0.80	GBU-8
△	FREESTREAM	0.90	GBU-8



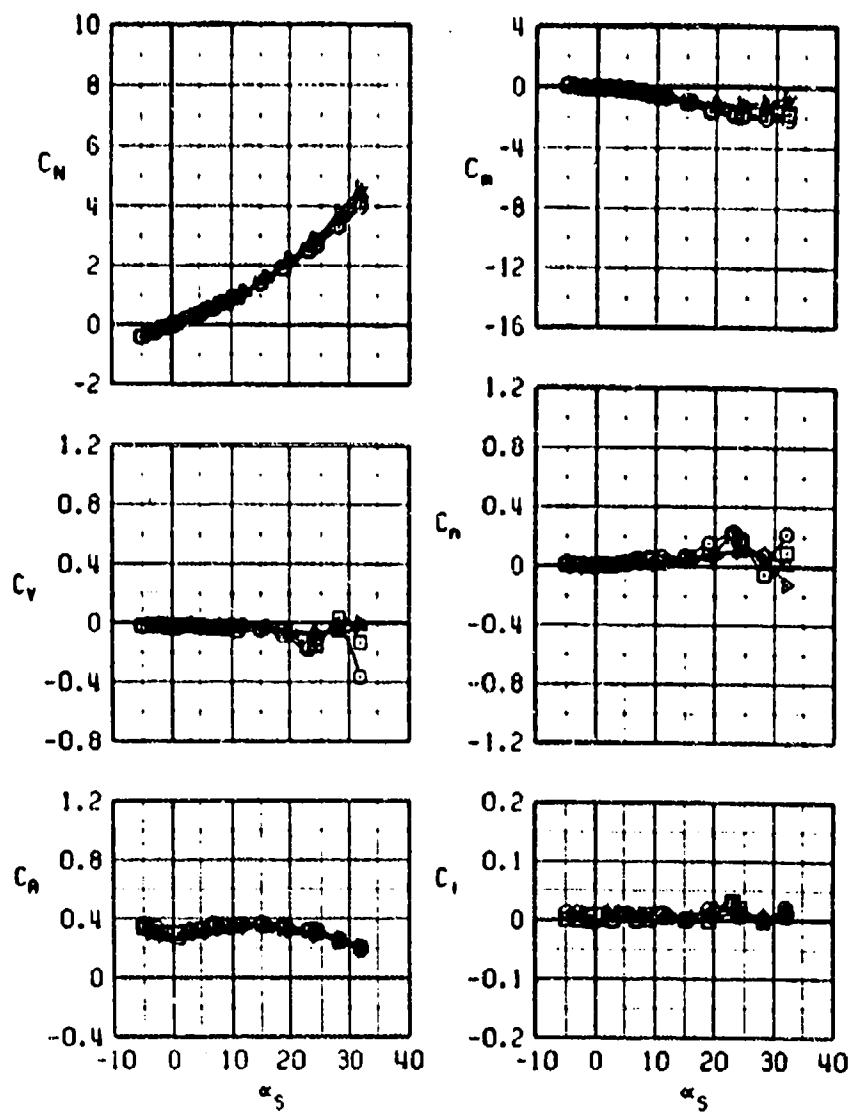
b. GBU-8
Figure 11. Continued.

SYMBOL	CONFIG	M_∞	STONE
▷	FREESTREAM	0.95	CBU-8
○	FREESTREAM	1.05	CBU-8
▽	FREESTREAM	1.20	CBU-8



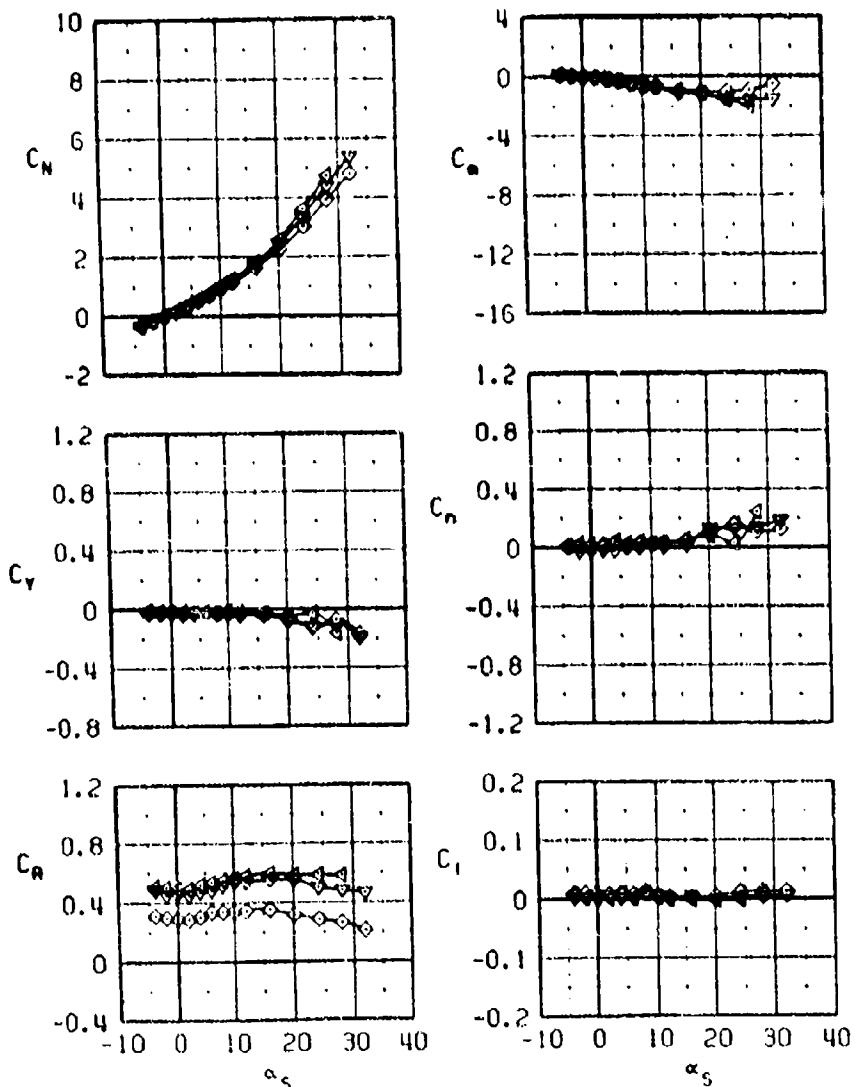
b. Concluded
Figure 11. Continued.

SYMBOL	CONFIG	M_∞	STORE
○	FREESTREAM	0.40	MK-82SE
□	FREESTREAM	0.60	MK-82SE
△	FREESTREAM	0.80	MK-82SE
▷	FREESTREAM	0.90	MK-82SE

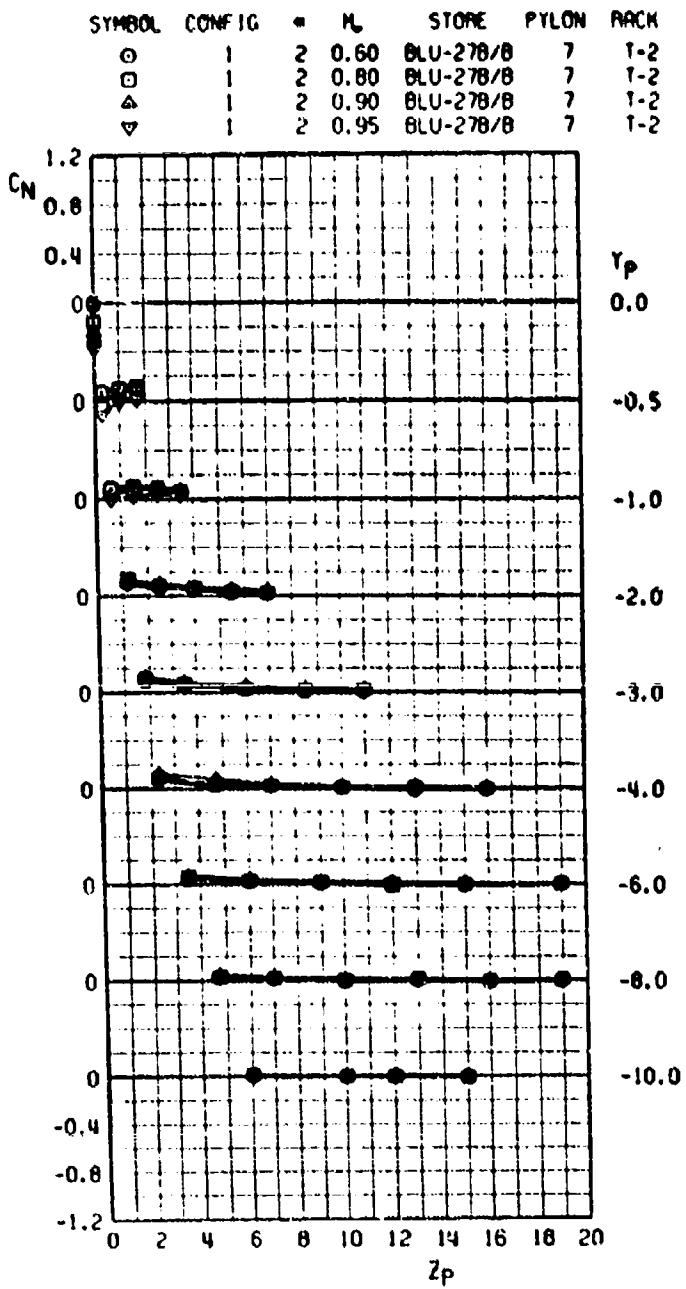


c. MK-82SE
Figure 11. Continued.

SYMBOL	CONFIG	M_∞	STORE
◊	FREESTREAM	0.95	MK-82SE
▽	FREESTREAM	1.05	MK-82SE
△	FREESTREAM	1.20	MK-82SE

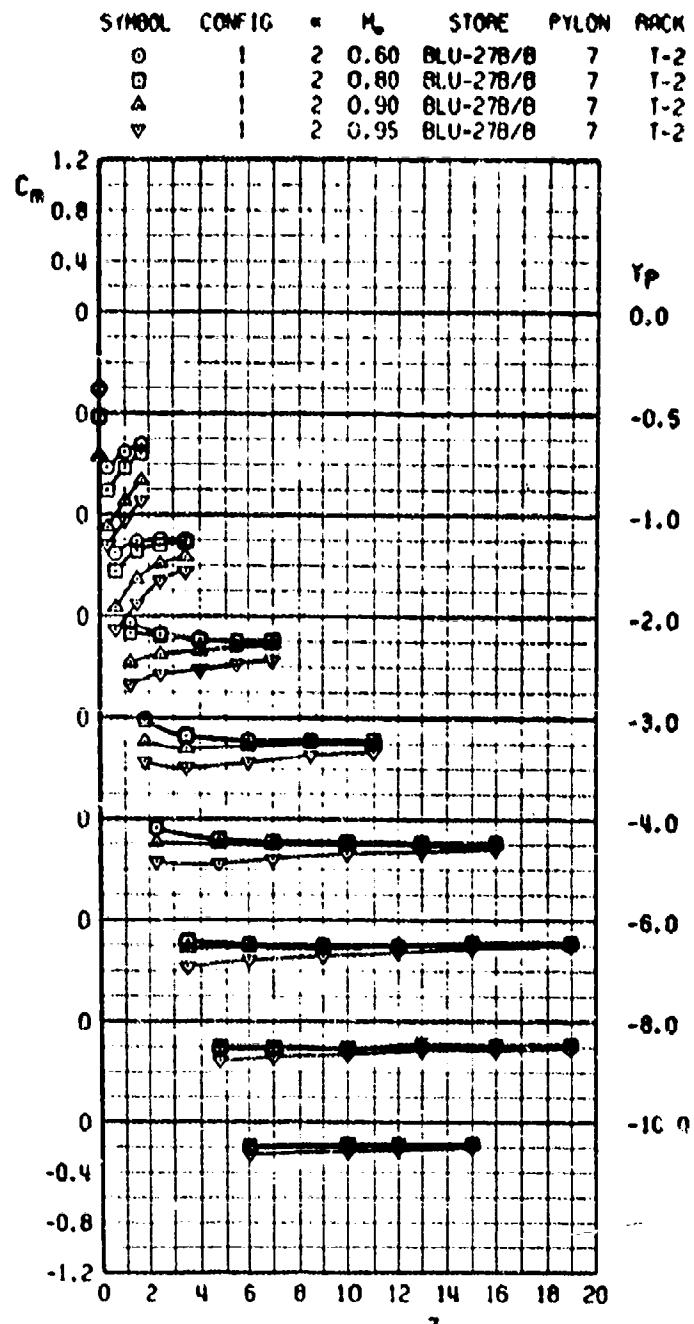


c. Concluded
Figure 11. Concluded.

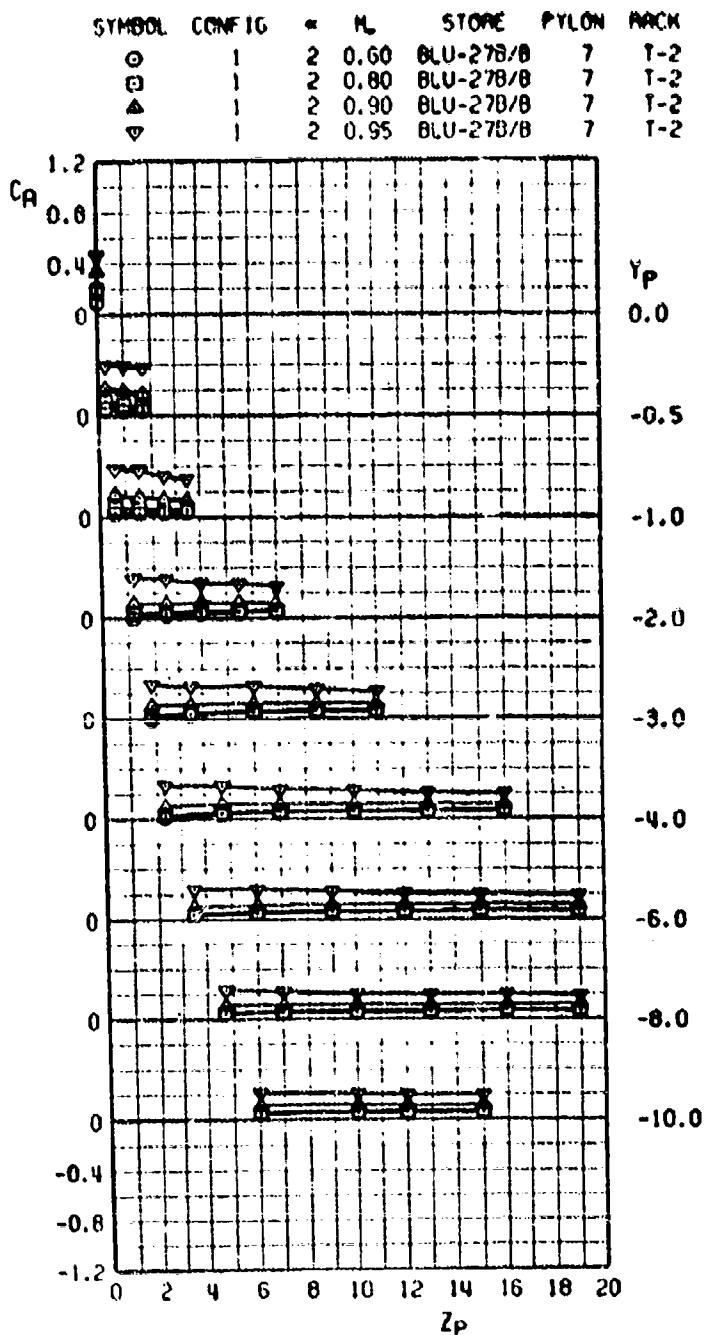


a. Normal-force coefficient

Figure 12. Aerodynamic characteristics of the BLU-278/B, configuration 1.

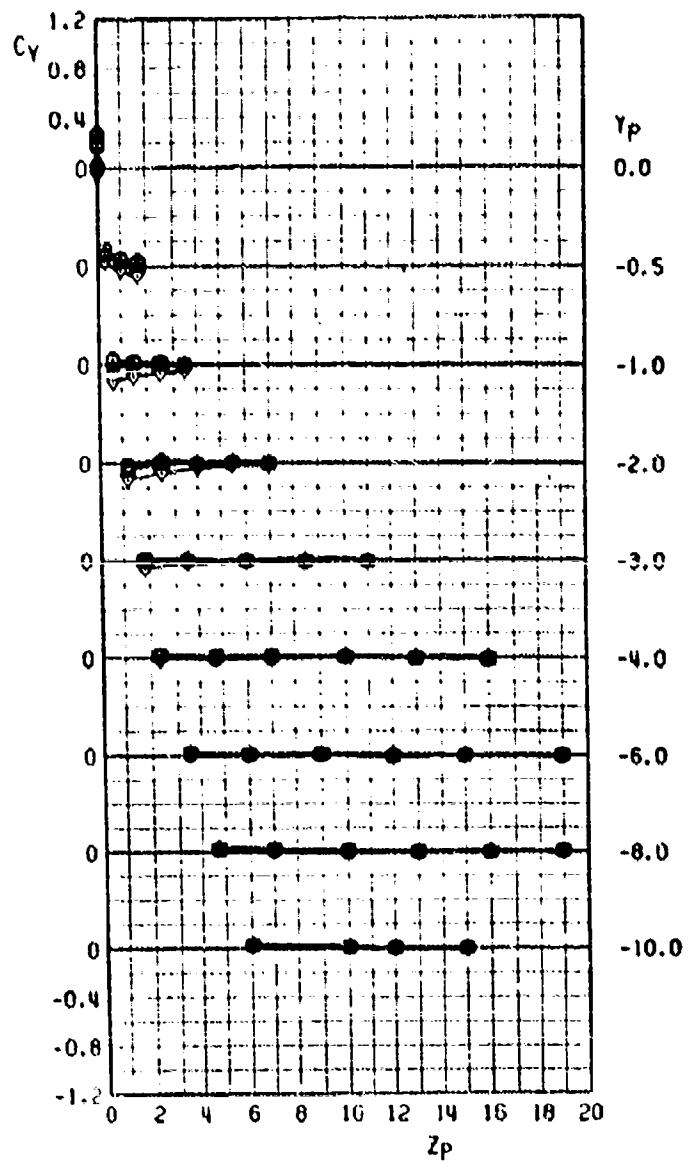


b. Pitching-moment coefficient
Figure 12. Continued.

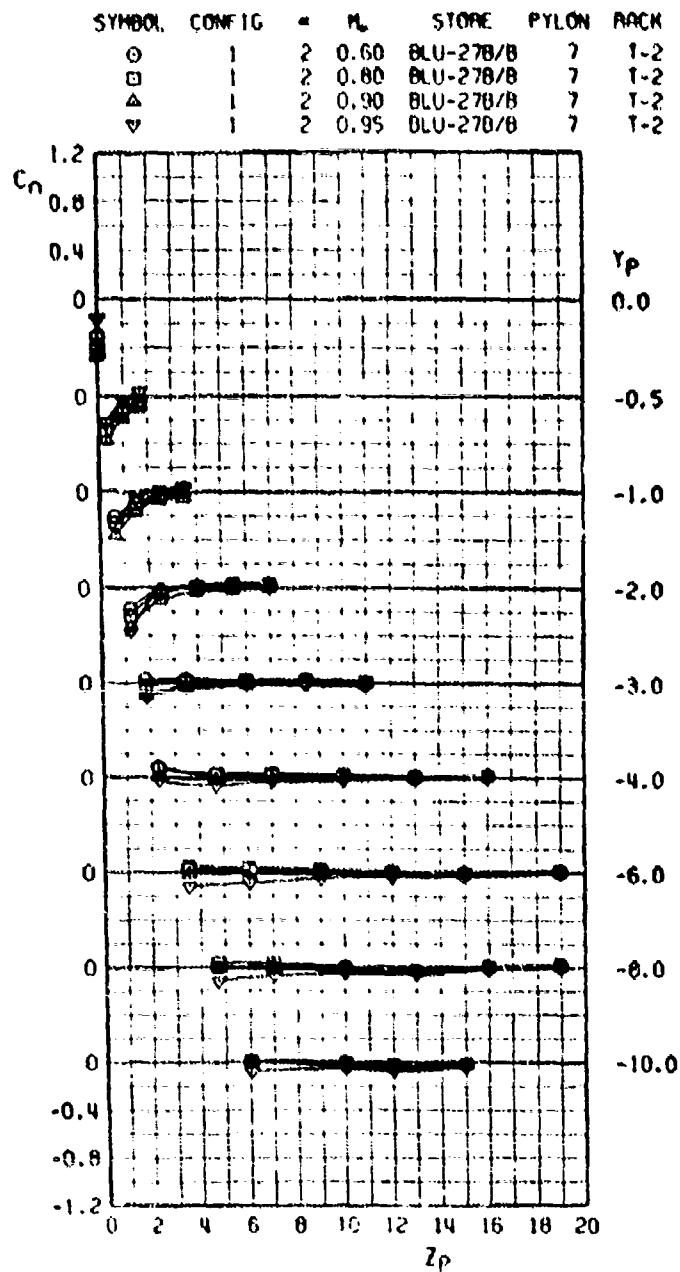


c. Axial-force coefficient
Figure 12. Continued.

SYMBOL	CONFIG	M_∞	STORE	PYLON	RACK
○	1	2	0.60	BLU-270/0	7
□	1	2	0.80	BLU-270/0	7
△	1	2	0.90	BLU-270/0	7
▽	1	2	0.95	BLU-270/0	7

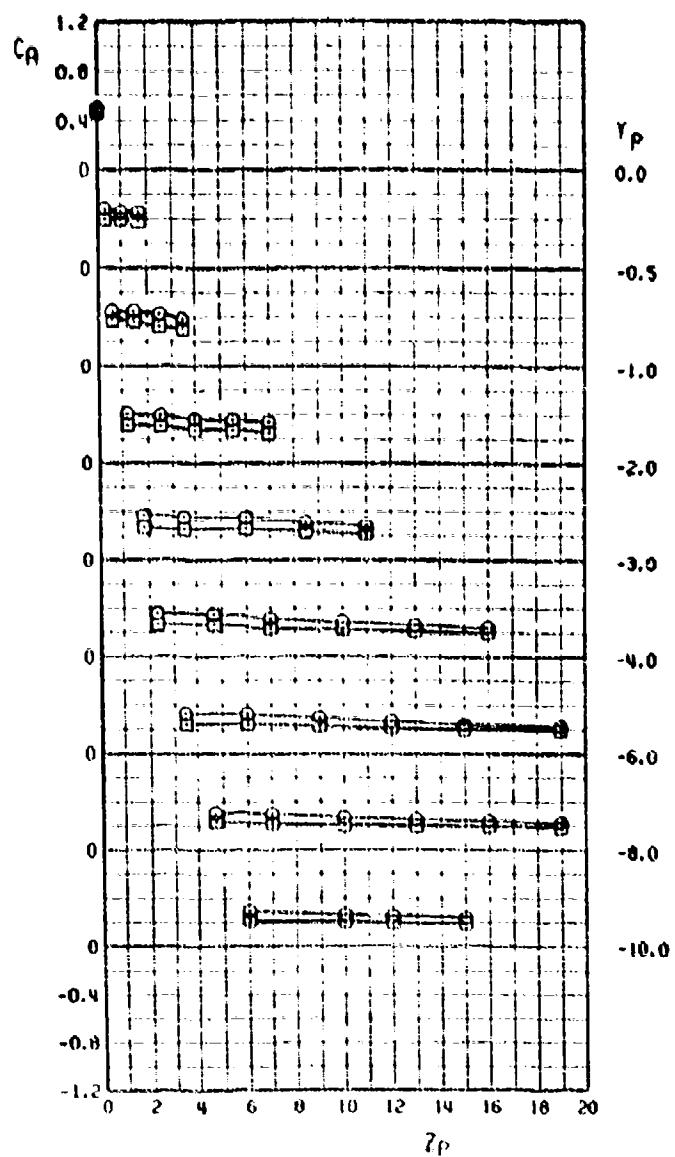


d. Side-force coefficient
Figure 12. Continued.



e. Yawing-moment coefficient
Figure 12. Concluded.

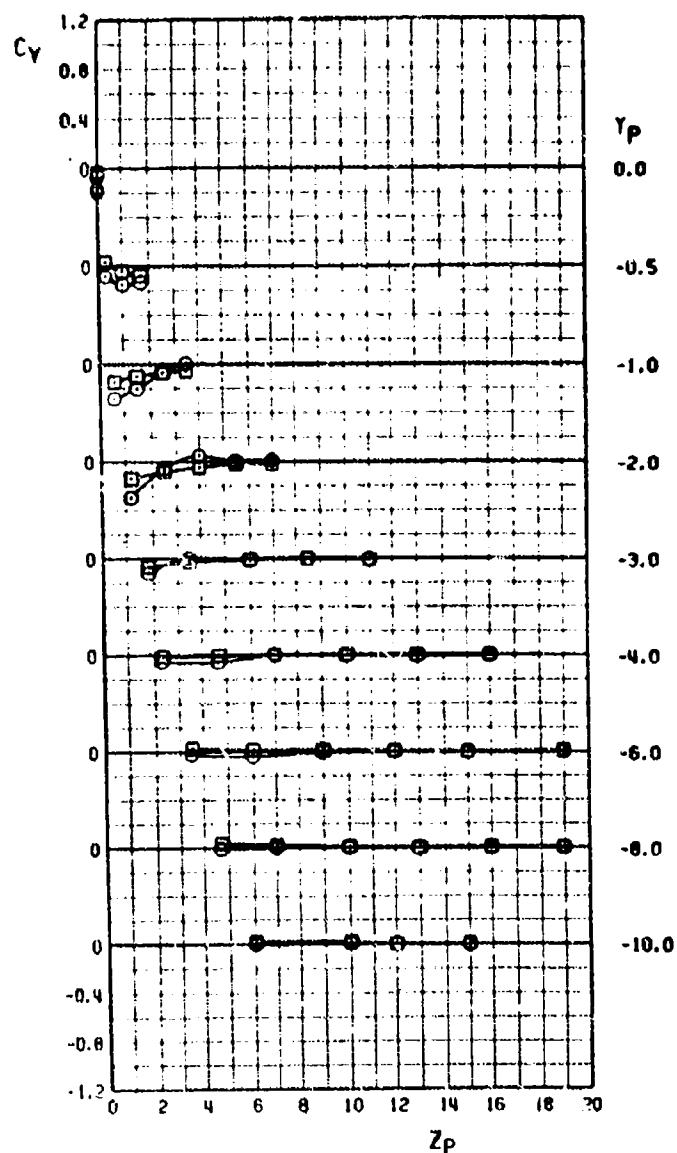
SYMBOL	CONFIG	α	M_∞	STORE	PYLON	RACK
○	1	0	0.95	BLU-27B/B	7	T-2
□	1	2	0.95	BLU-27B/B	7	T-2



a. Axial-force coefficient

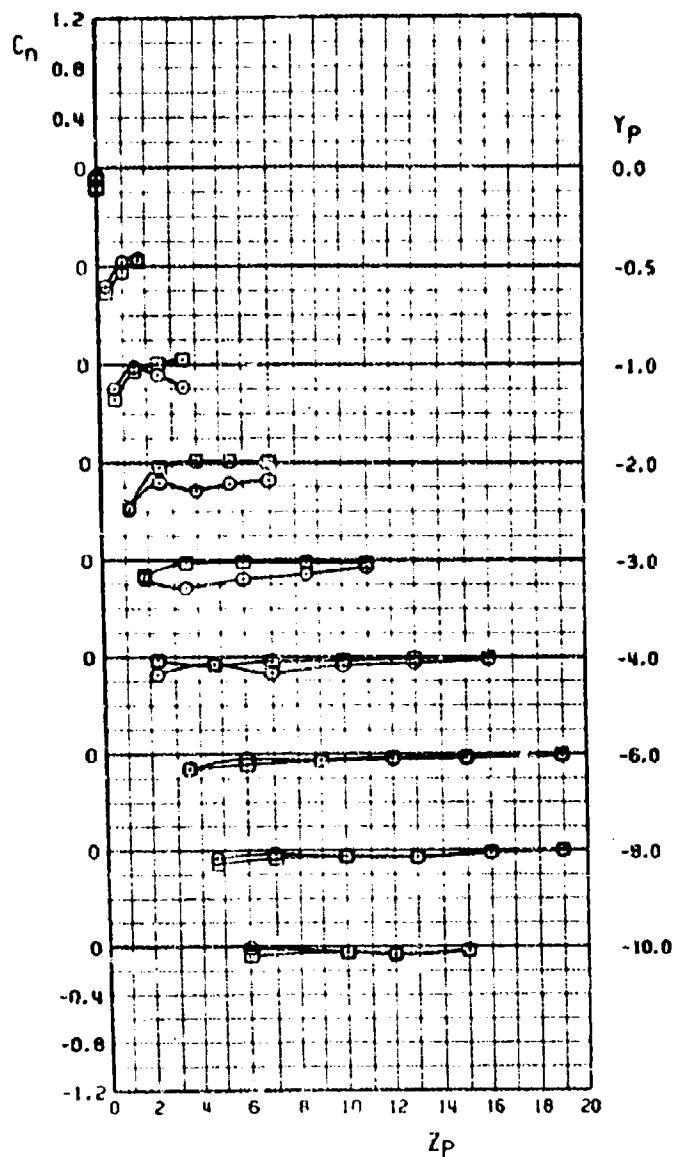
Figure 13. BLU-27B/B coefficient variation with aircraft angle of attack, configuration 1.

SYMBOL	CONFIG	α	M_∞	STORE	PYLON	RACK
○	1	0	0.95	BLU-27B/B	7	T-2
□	1	2	0.95	BLU-27B/B	7	T-2



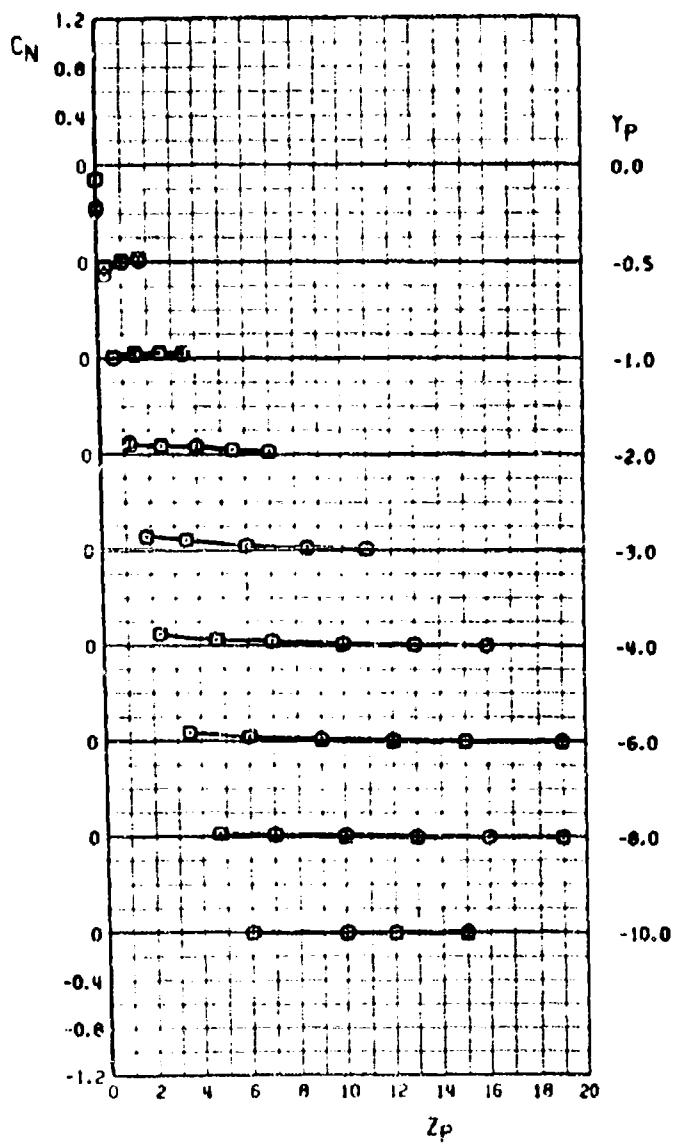
b. Side-force coefficient
Figure 13. Continued.

SYMBOL	CONFIG	M_e	STORE	PYLON	RACK	
0	1	0	0.95	BLU-27B/B	7	T-2
0	1	2	0.95	BLU-27B/B	7	T-2



c. Yawing-moment coefficient
Figure 13. Concluded.

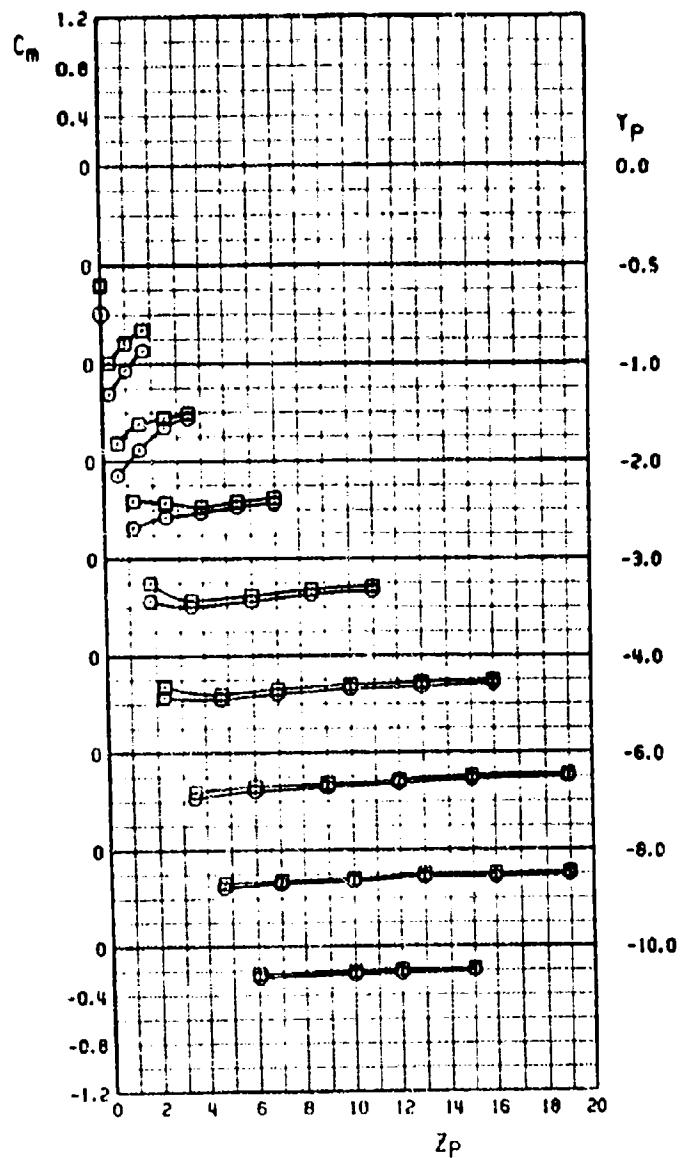
SYMBOL	CONFIG	α	M_∞	STORE	PYLON	RACK
○	1	2	0.95	BLU-27B/B	7	1-2
□	2	2	0.95	BLU-27B/B	7	1-2



a. Normal-force coefficient

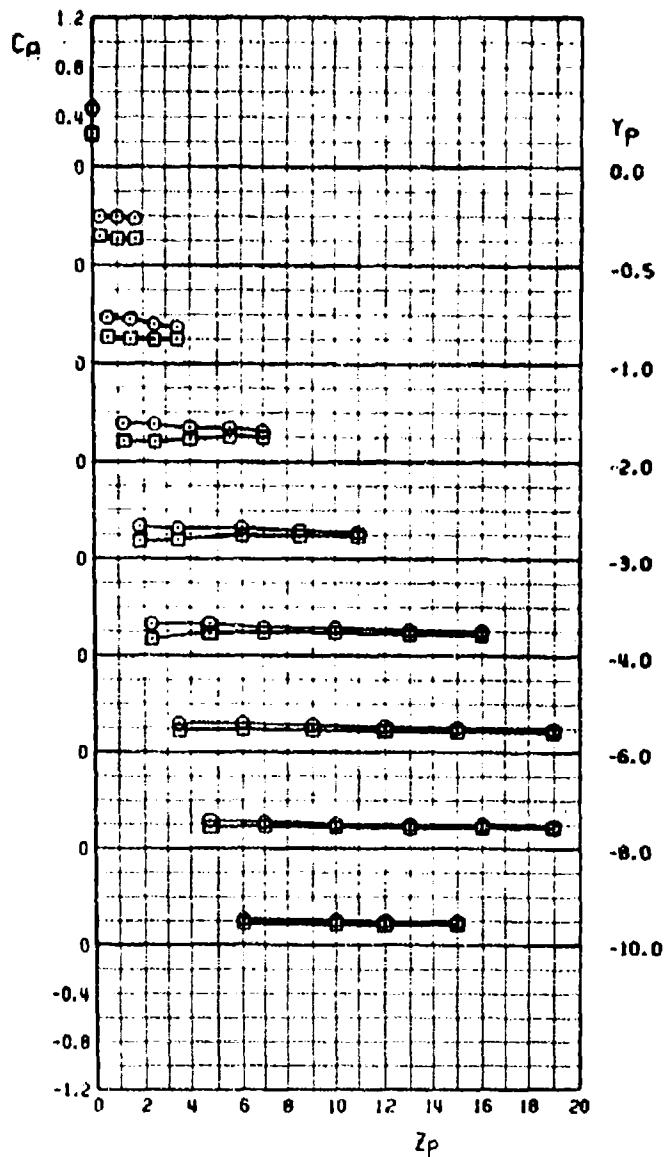
Figure 14. Effect of an adjacent store on the BLU-27B/B,
configurations 1 and 2.

SYMBOL	CONFIG	α	M_∞	STORE	PYLON	RACK
○	1	2	0.95	BLU-27B/B	7	T-2
□	2	2	0.95	BLU-27B/B	7	T-2



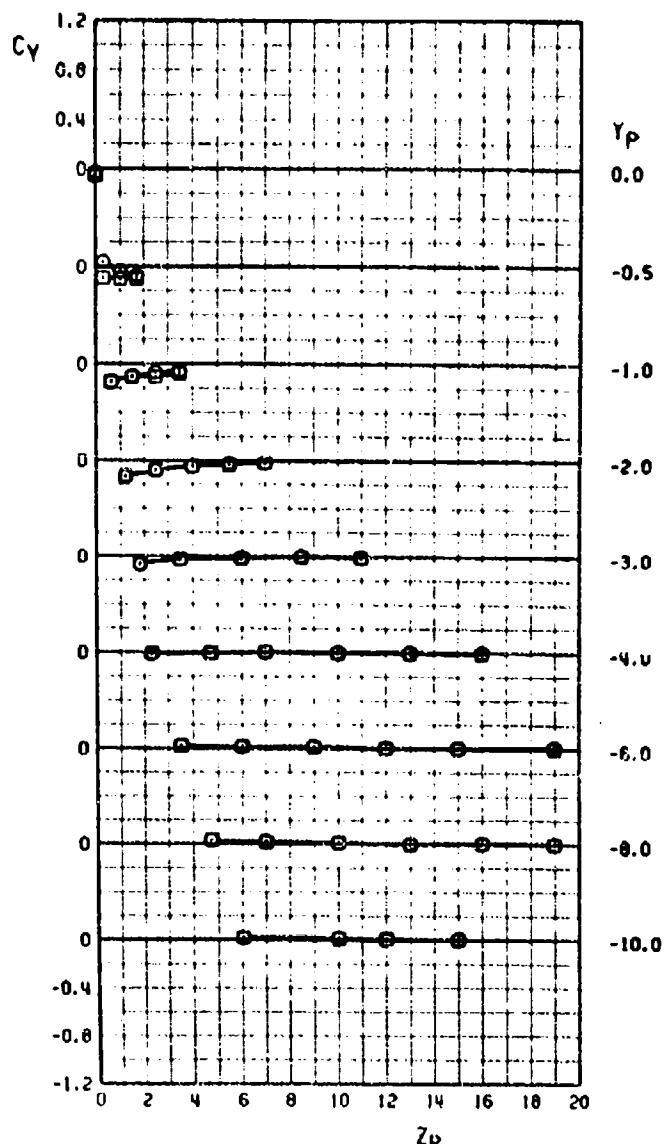
b. Pitching-moment coefficient
Figure 14. Continued.

SYMBOL	CONFIG	∞	M_∞	STORE	PYLON	RACK
○	1	2	0.95	BLU-278/B	7	T-2
□	2	2	0.95	BLU-278/B	7	T-2



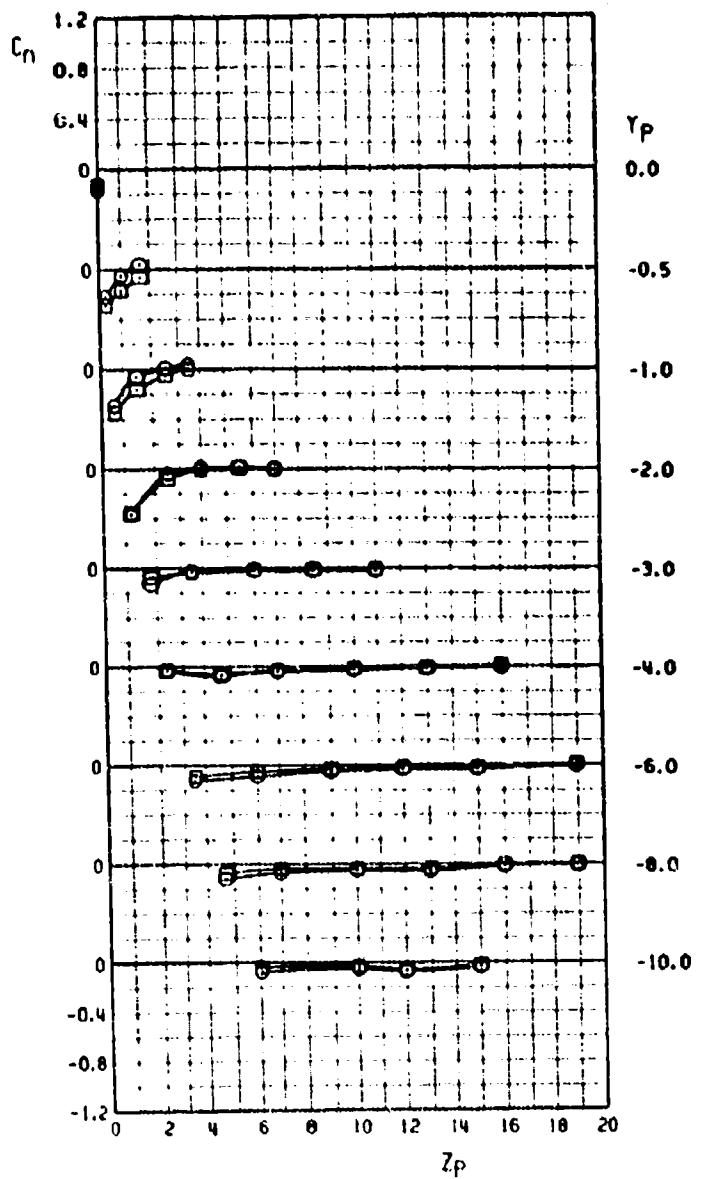
c. Axial-force coefficient
Figure 14. Continued.

SYMBOL	CONFIG	M_∞	STORE	PYLON	RACK	
○	1	2	0.95	BLU-27B/B	7	T-2
□	2	2	0.95	BLU-27B/B	7	T-2

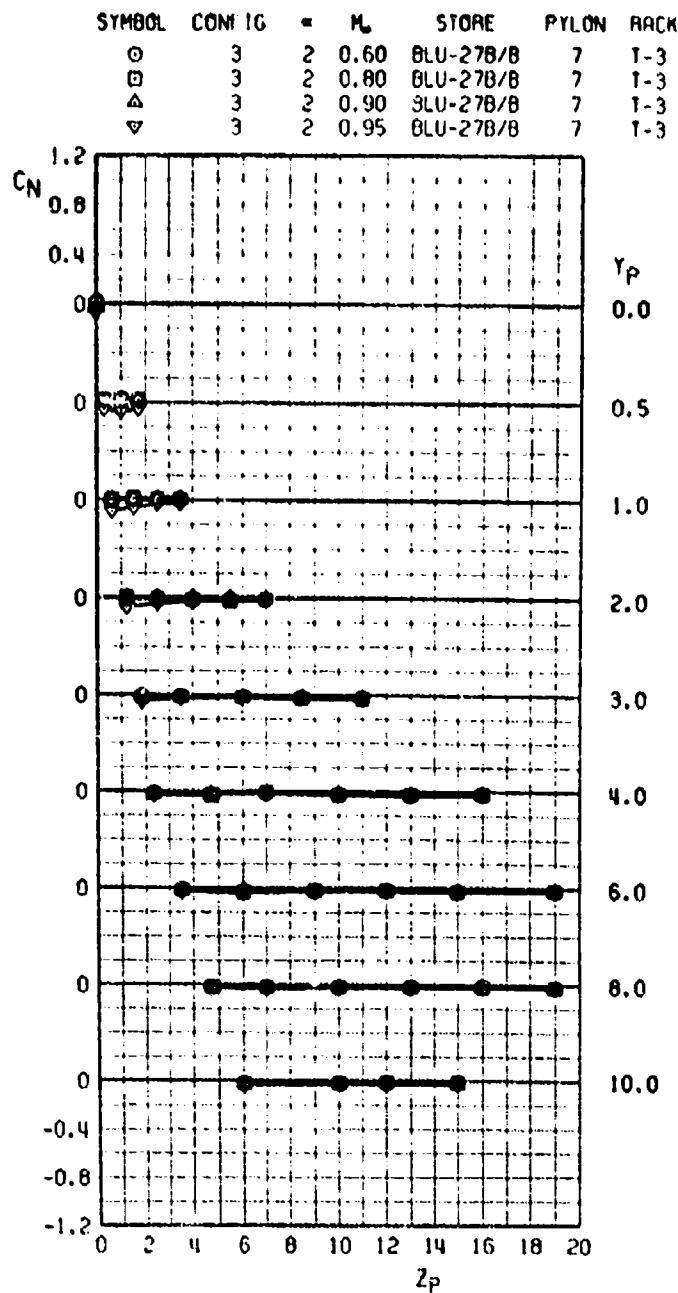


d. Side-force coefficient
Figure 14. Continued.

SYMBOL	CONFIG	M_e	STORE	PYLON	RACK
○	1	2	0.95	BLU-278/B	7
□	2	2	0.95	BLU-278/B	7



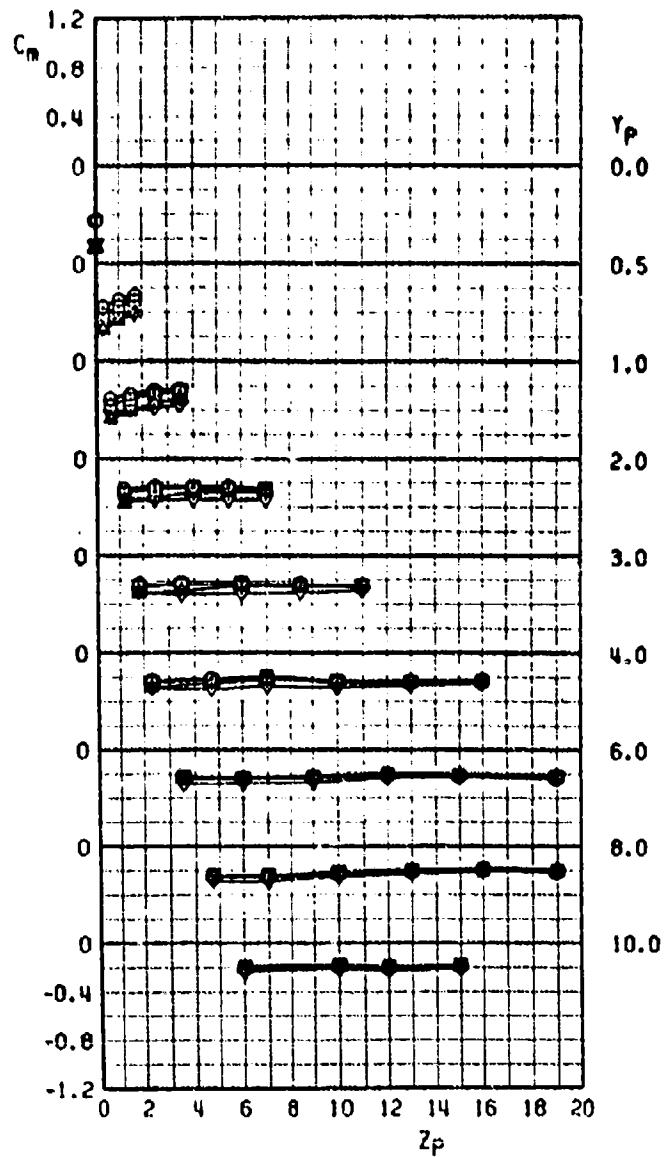
e. Yawing-moment coefficient
Figure 14. Concluded.



a. Normal-force coefficient

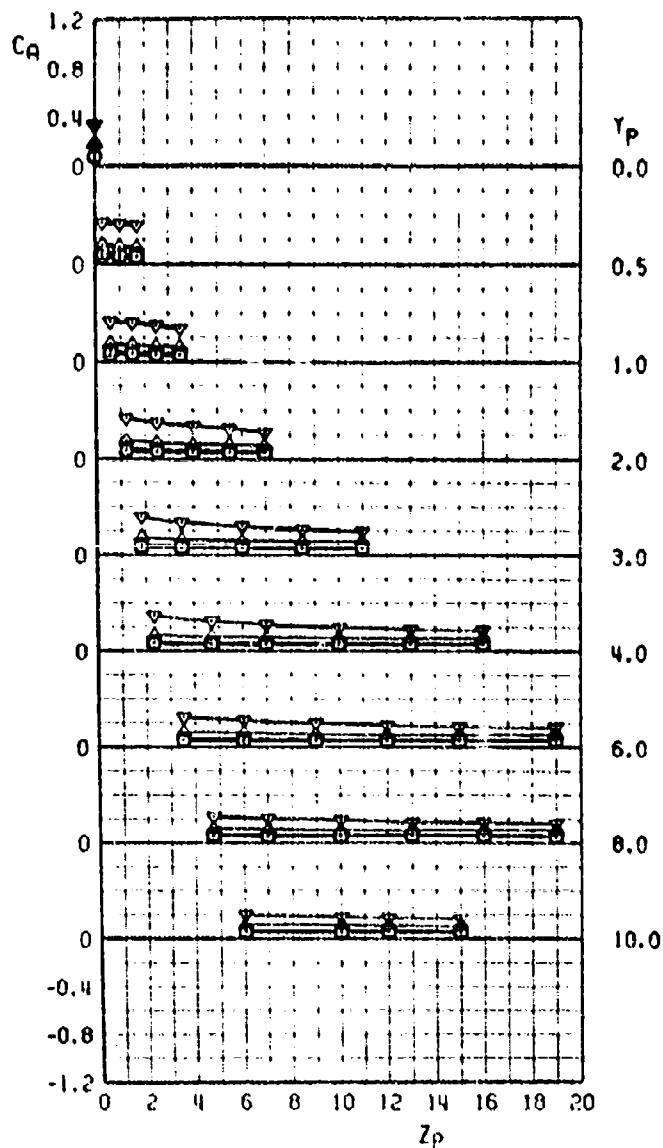
Figure 15. Aerodynamic characteristics of the BLU-27B/B, configuration 3.

SYMBOL	CONFIG	α	M_∞	STORE	PYLON	RACK
○	3	2	0.60	BLU-27B/0	7	1-3
□	3	2	0.80	BLU-27B/8	7	1-3
△	3	2	0.90	BLU-27B/0	7	1-3
▽	3	2	0.95	BLU-27B/8	7	1-3



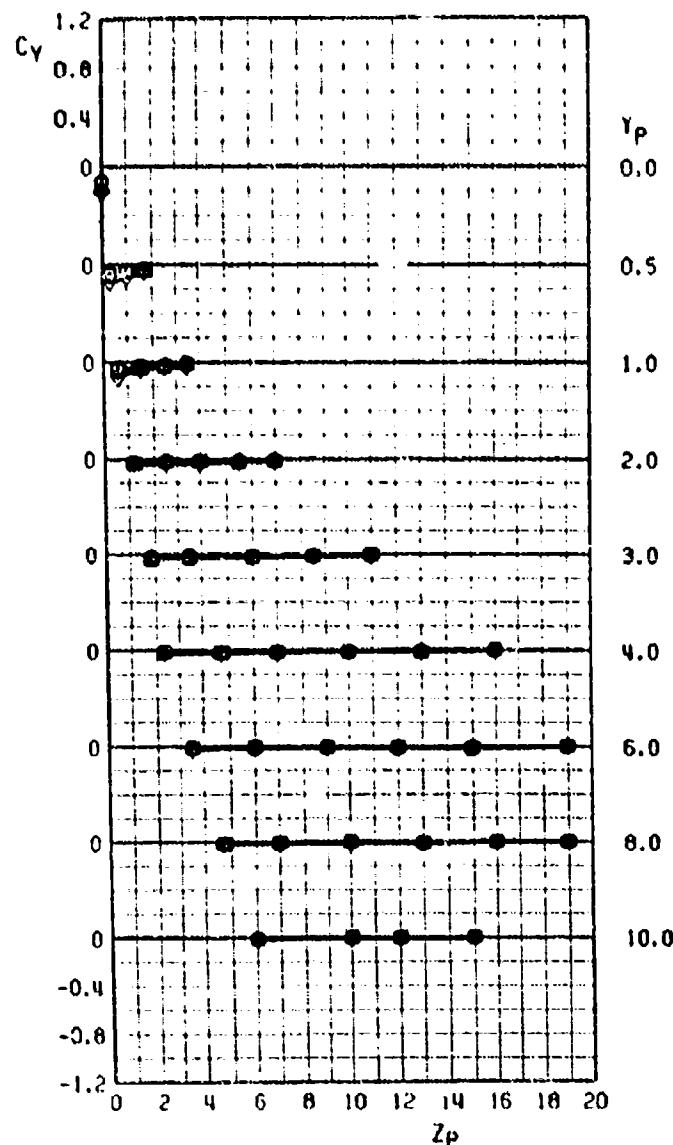
b. Pitching-moment coefficient
Figure 15. Continued.

SYMBOL	CONFIG	α	M _∞	STORE	PYLON	RACK
○	3	2	0.60	BLU-278/B	7	T-3
□	3	2	0.80	BLU-278/B	7	T-3
△	3	2	0.90	BLU-278/B	7	T-3
▽	3	2	0.95	BLU-278/B	7	T-3



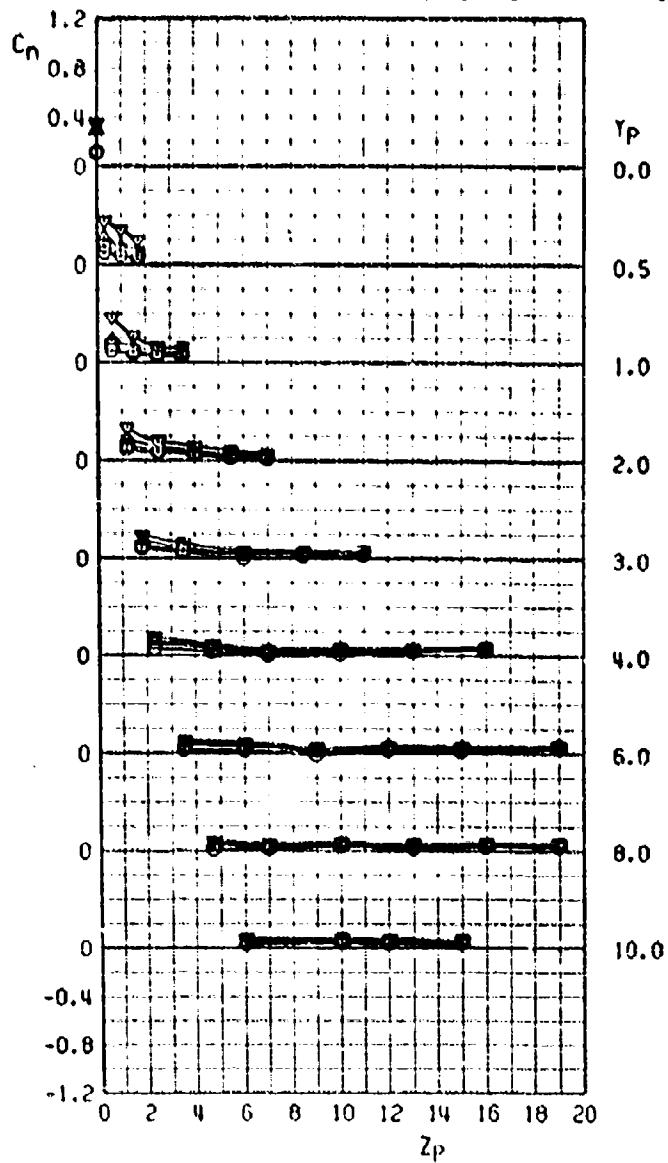
c. Axial-force coefficient
Figure 15. Continued.

SYMBOL	CONFIG	* M_a	STORE	PYLON	RACK	
○	3	2	0.60	BLU-27B/B	7	1-3
□	3	2	0.80	BLU-27B/B	7	1-3
△	3	2	0.90	BLU-27B/B	7	1-3
▽	3	2	0.95	BLU-27D/B	7	1-3



d. Side-force coefficient
Figure 15. Continued.

SYMBOL	CONFIG	α	M_∞	STORE	PYLON	RACK
○	3	2	0.60	BLU-270/0	7	T-3
□	3	2	0.00	BLU-270/0	7	T-3
△	3	2	0.90	BLU-270/0	7	T-3
▽	3	2	0.95	BLU-270/0	7	T-3



e. Yawing-moment coefficient
Figure 15. Concluded.

SYMBOL	CONFIG	α	M_∞	STORE	PYLON	RACK
○	3	0	0.90	BLU-27B/B	7	T-3
□	3	2	0.90	BLU-27B/B	7	T-3

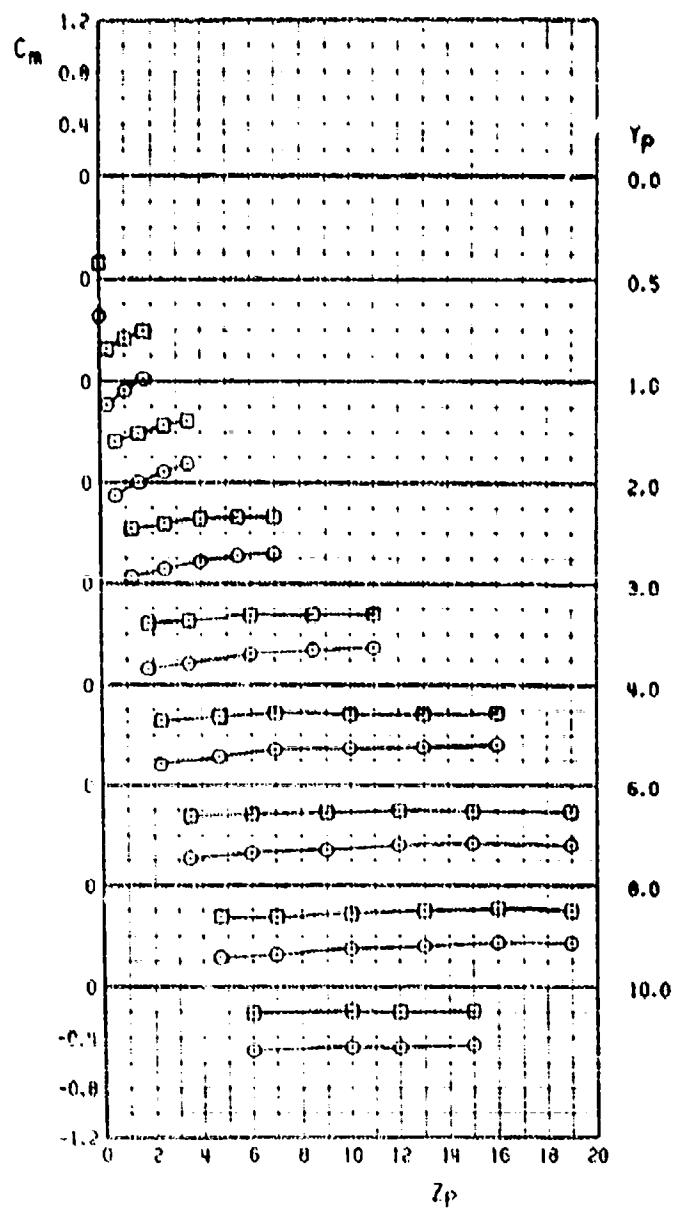
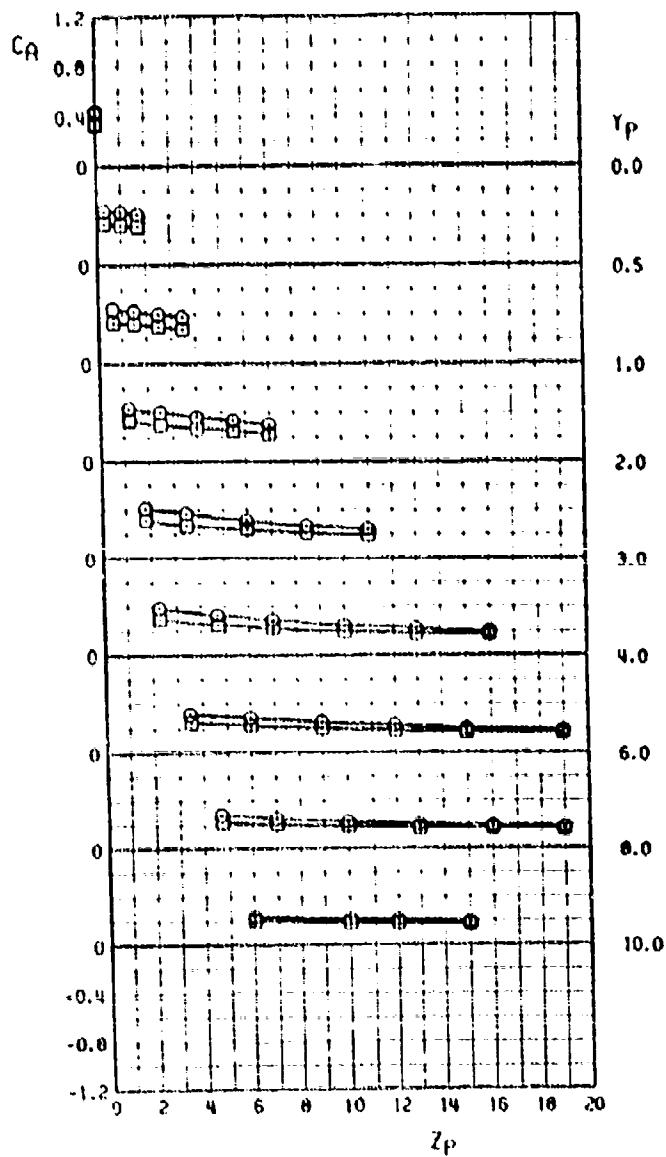
a. Pitching-moment coefficient, $M_\infty = 0.9$

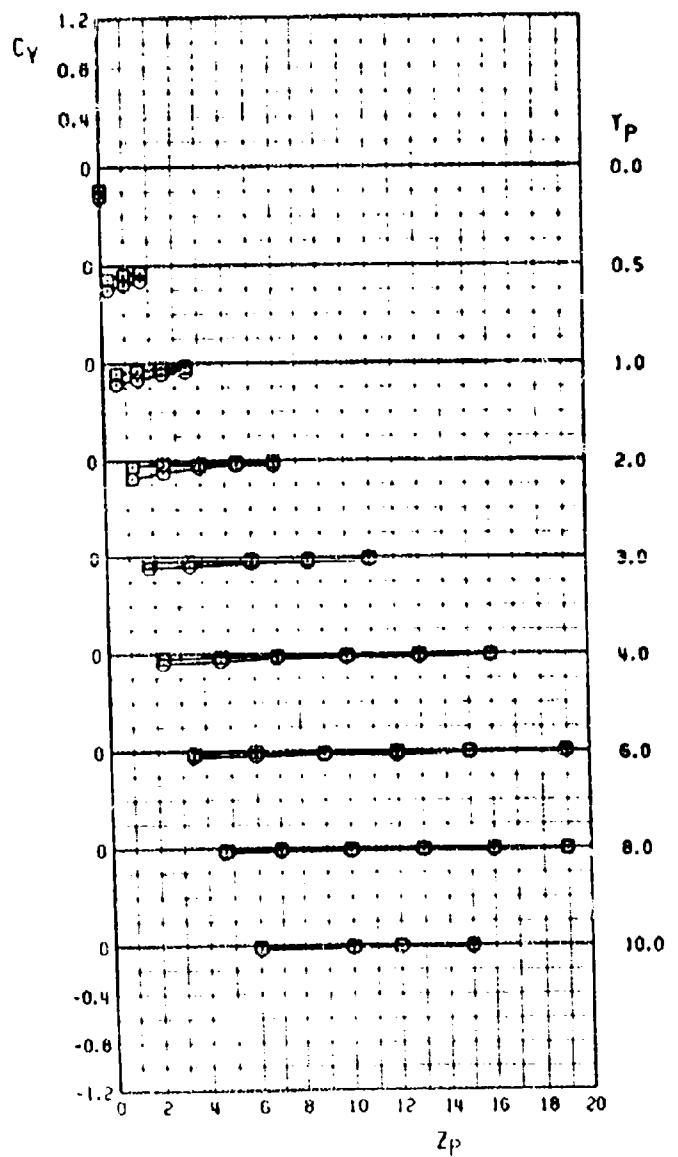
Figure 16. BLU-27B/B coefficient variation with aircraft angle of attack, configuration 3.

SYMBOL	CONFIG	∞	M_∞	STONE	PYLON	RACK
○	3	0	0.95	BLU-27B/0	7	T-3
□	3	2	0.95	BLU-27B/0	7	T-3



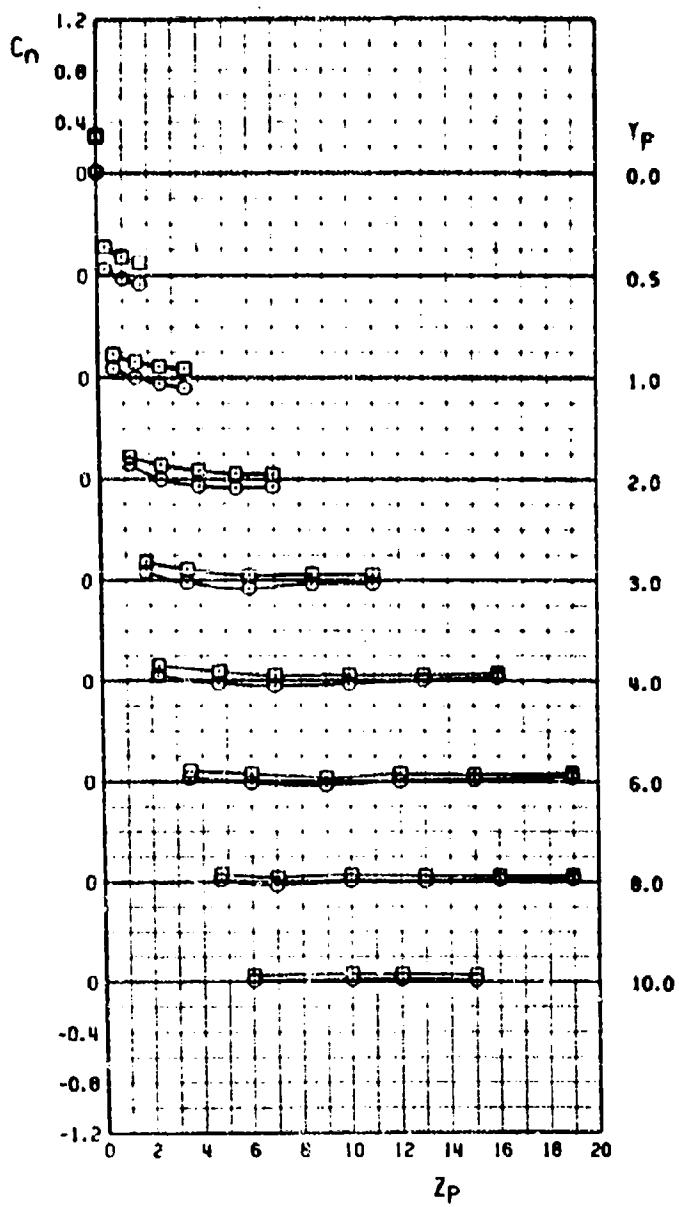
b. Axial-force coefficient, $M_\infty = 0.95$
 Figure 16. Continued.

SYMBOL	CONFIG	α	M_∞	STORE	PYLON	PACK
○	3	0	0.90	BLU-278/B	7	1-3
□	3	2	0.90	BLU-278/B	7	1-3



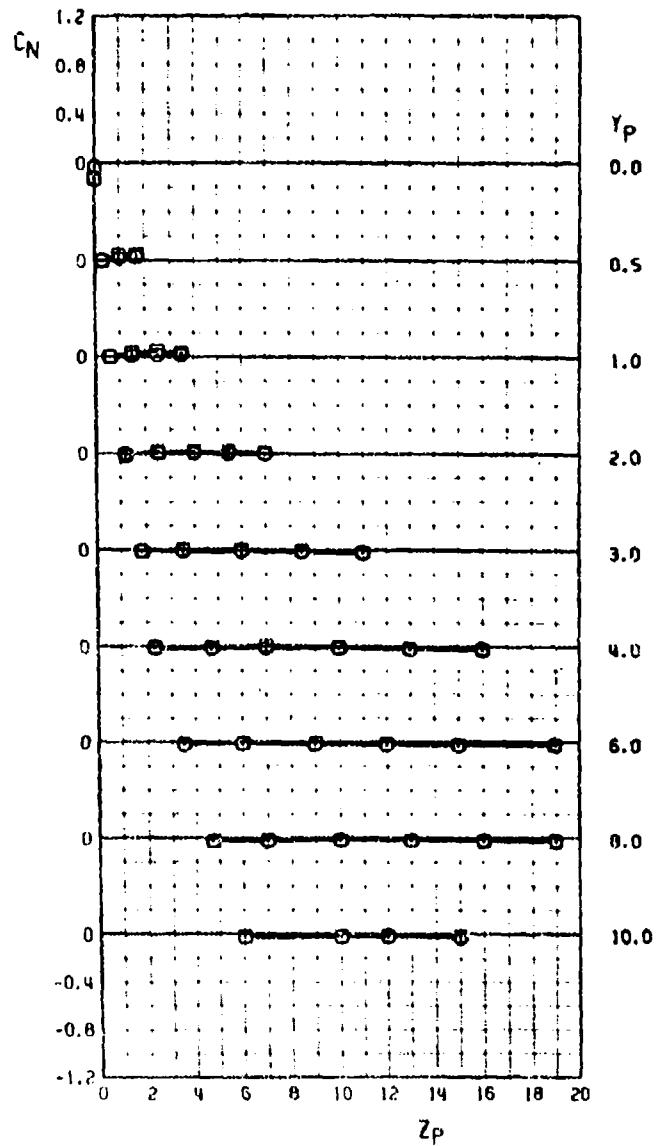
c. Side-force coefficient
Figure 16. Continued.

SYMBOL	CONFIG	α	M_a	STORE	PYLON	RACK
○	3	0	0.90	BLU-278/8	7	1-3
□	3	2	0.90	BLU-278/8	7	1-3



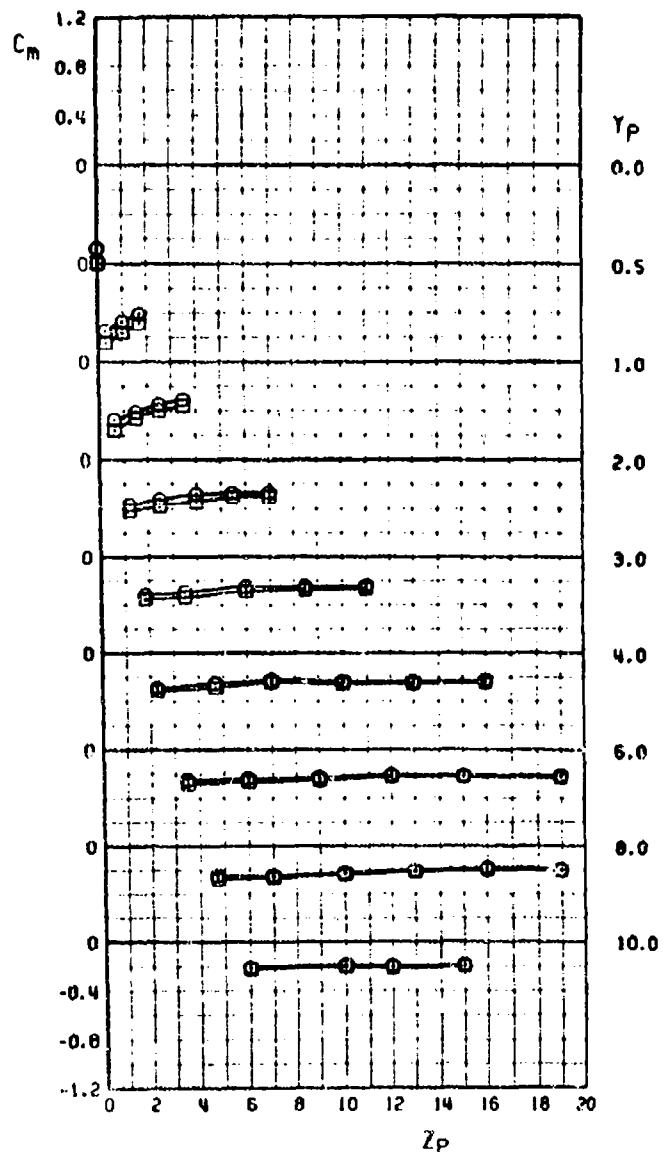
d. Yawing-moment coefficient
Figure 16. Concluded.

SYMBOL	CONFIG	α	M_∞	STORE	PYLON	RACK
○	3	2	0.90	BLU-27B/B	7	T-3
□	4	2	0.90	BLU-27B/B	7	T-3



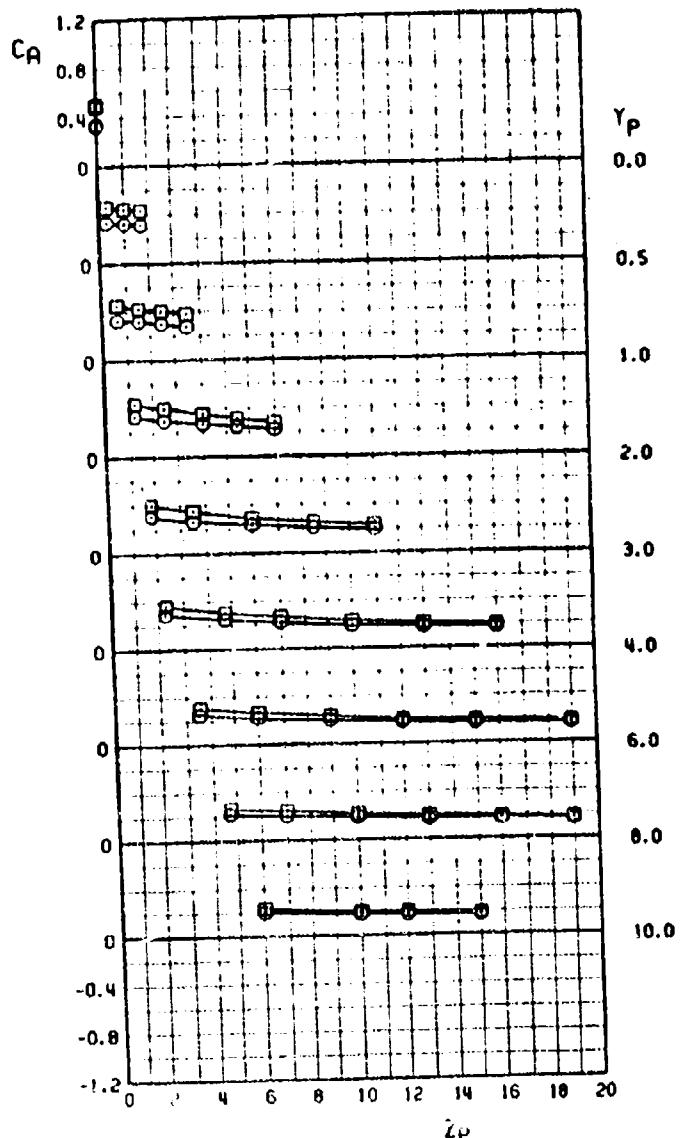
a. Normal-force coefficient, $M_\infty = 0.9$
**Figure 17. Effect of an adjacent store on the BLU-27B/B,
 configurations 3 and 4.**

SYMBOL	CONFIG	α	M_∞	STORE	PYLON	RACK
○	3	2	0.90	BLU-27B/8	7	T-3
□	4	2	0.90	BLU-27B/8	7	T-3



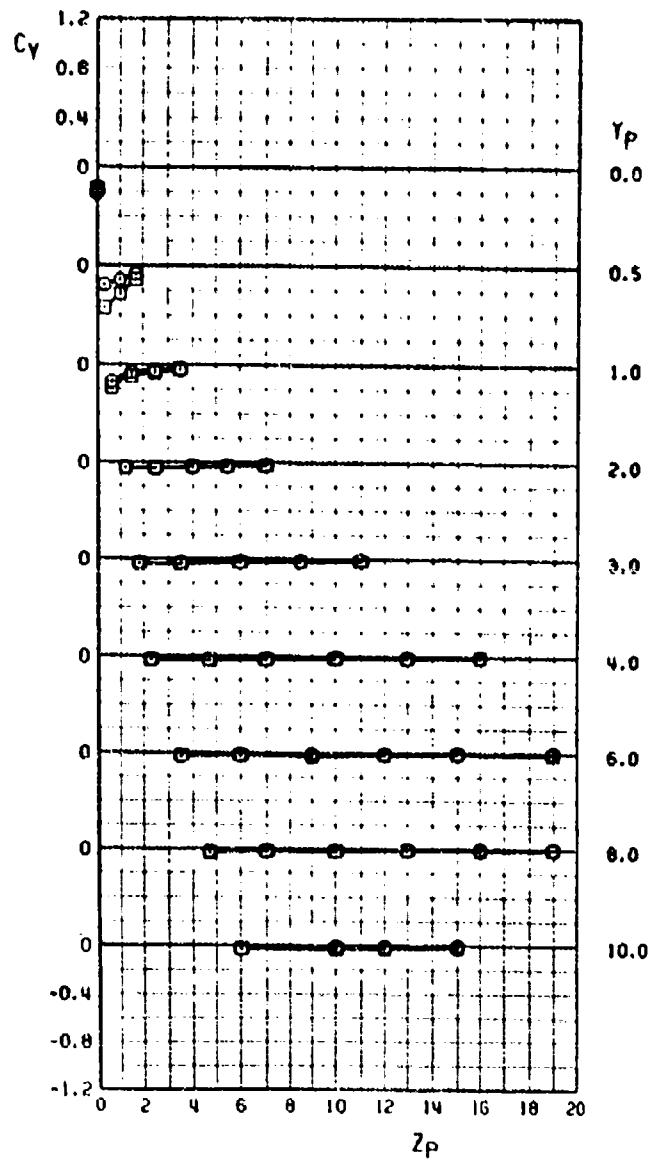
b. Pitching-moment coefficient, $M_\infty = 0.9$
Figure 17. Continued.

SYMBOL	CONFIG	α	M_∞	STORE	PYLON	RACK
○	3	2	0.95	BLU-27B/B	7	1-3
□	4	2	0.95	BLU-27B/B	7	1-3



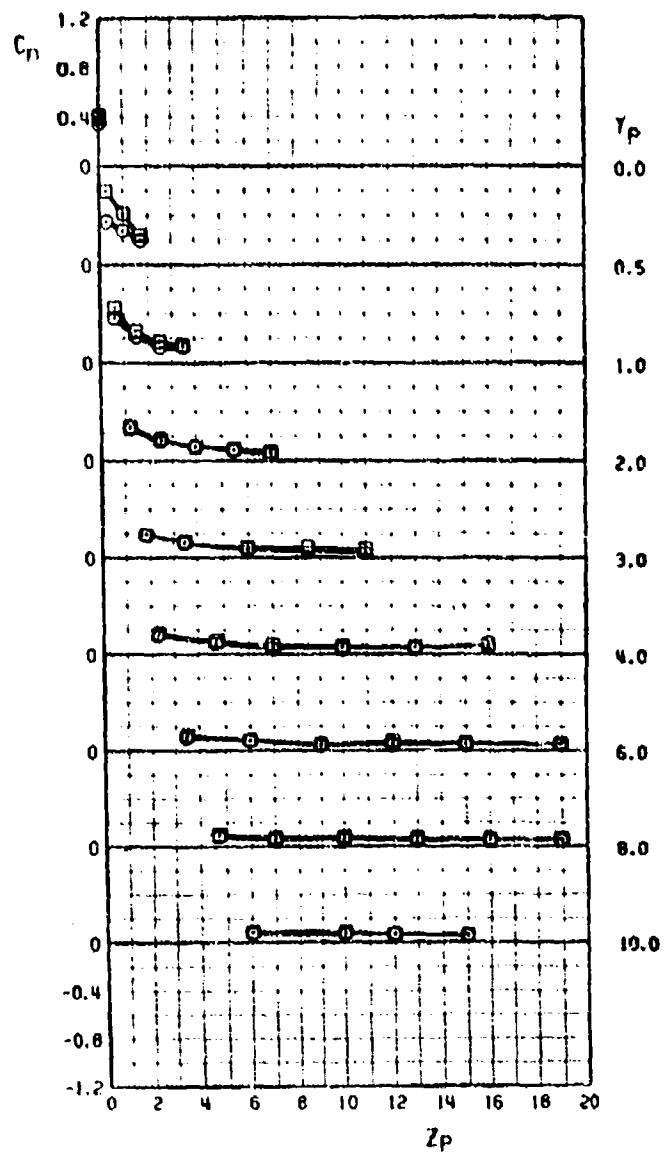
c. Axial-force coefficient, $M_\infty = 0.95$
Figure 17. Continued.

SYMBOL	CONFIG	M_∞	STORE	PYLON	NACK	
○	3	2	0.95	BLU-270/B	7	1-3
□	4	2	0.95	BLU-270/B	7	1-3



d. Side-force coefficient, $M_\infty = 0.95$
Figure 17. Continued.

SYMBOL	CONFIG	α	M_∞	STORE	PYLON	RACK
○	3	2	0.95	BLU-27B/8	7	T-3
□	4	2	0.95	BLU-27B/8	7	T-3



e. Yawing-moment coefficient, $M_\infty = 0.95$
Figure 17. Concluded.

SYMBOL	CONFIG	M_∞	STORE	PYLON
○	5	2 0.60	BLU-27B/B	7
□	5	2 0.80	BLU-27B/B	7
△	5	2 0.90	BLU-27B/B	7
▽	5	2 0.95	BLU-27B/B	7

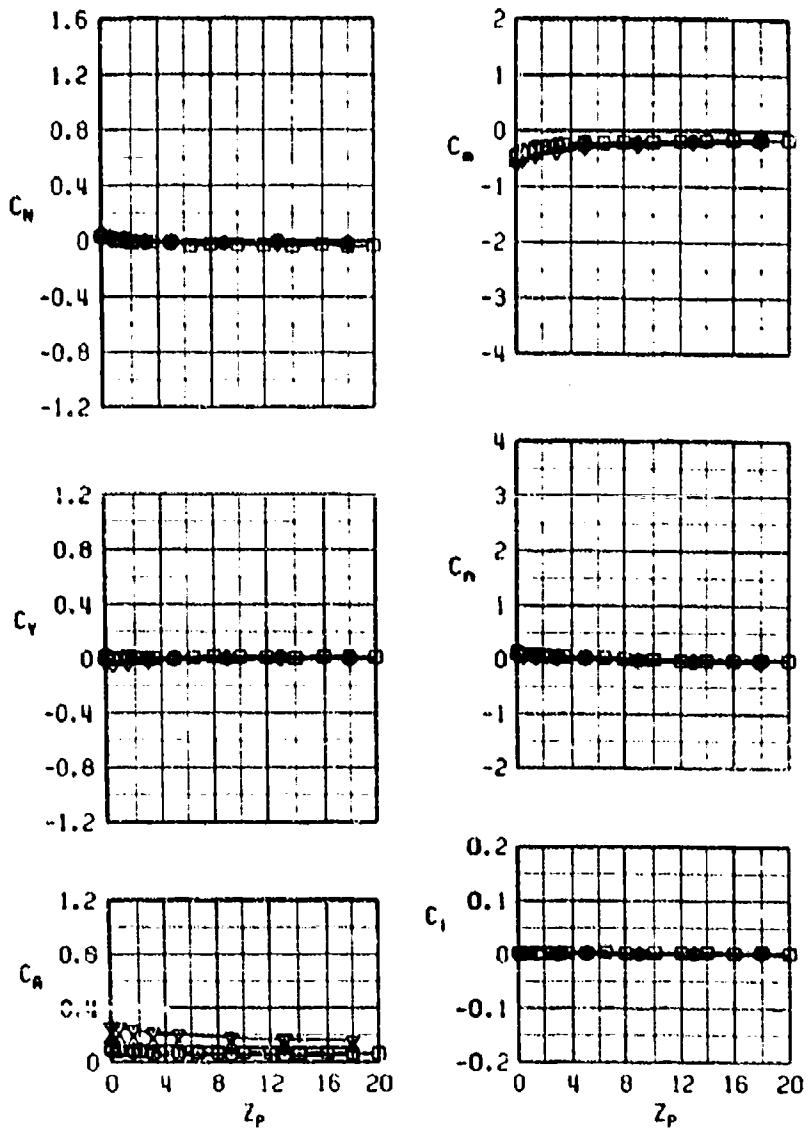


Figure 18. Aerodynamic characteristics of the BLU-27B/B, configuration 5.

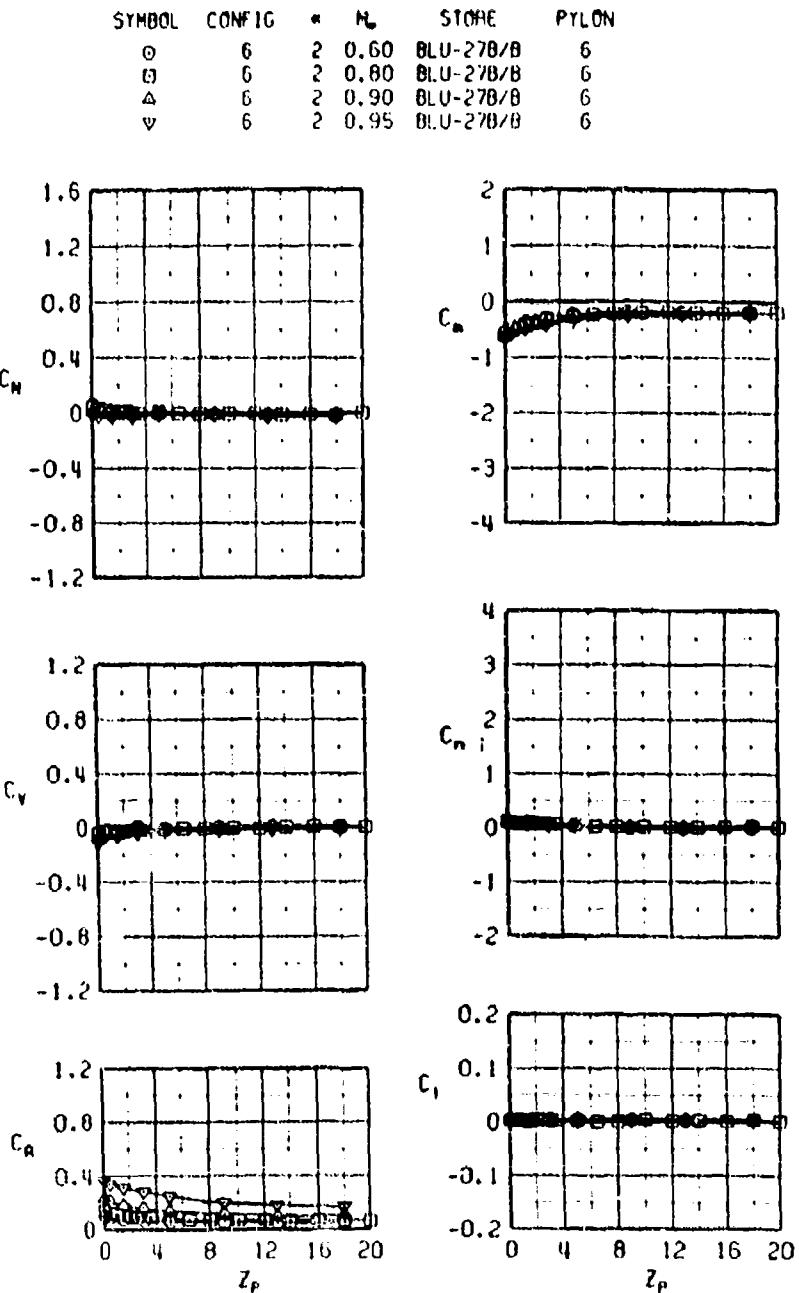


Figure 19. Aerodynamic characteristics of the BLU-27B/B, configuration 6.

SYMBOL	CONFIG	α	M_∞	STONE	PYLON
○	7	0	0.80	GBU-8	7
□	7	0	0.90	GBU-8	7
△	7	0	0.95	GBU-8	7
▽	7	0	1.05	GBU-8	7
▷	7	0	1.20	GBU-8	7

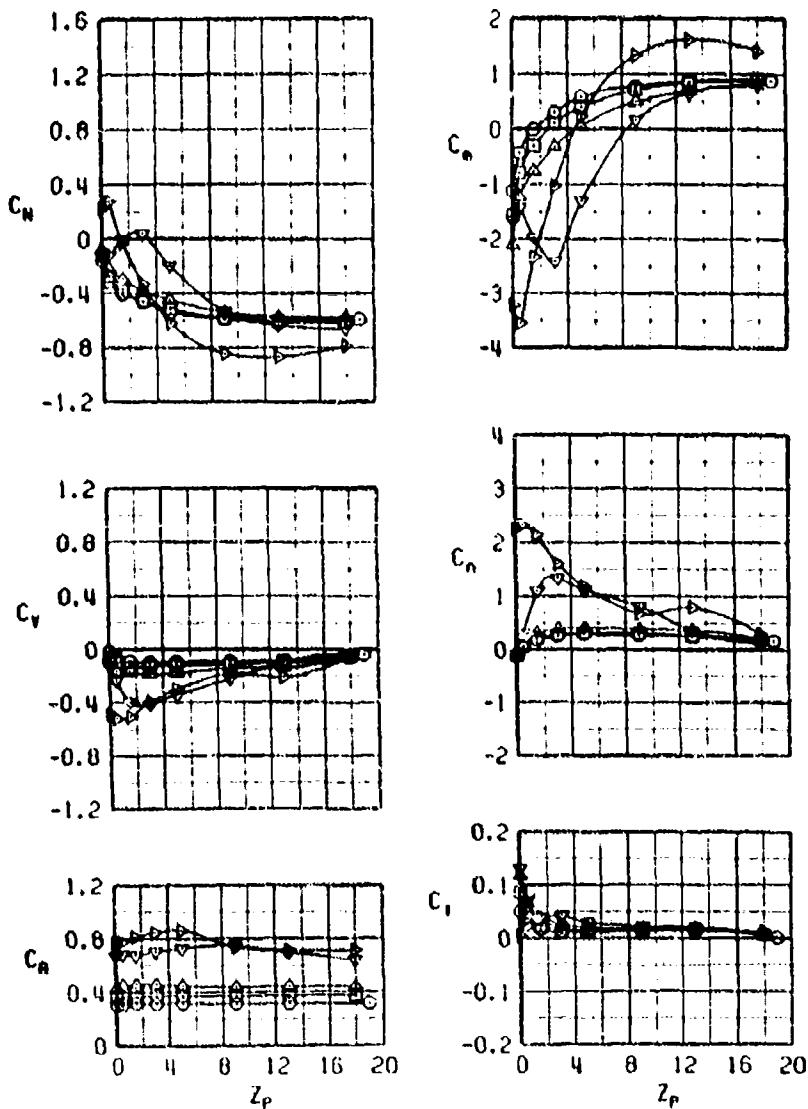


Figure 20. Aerodynamic characteristics of the GBU-8, configuration 7.

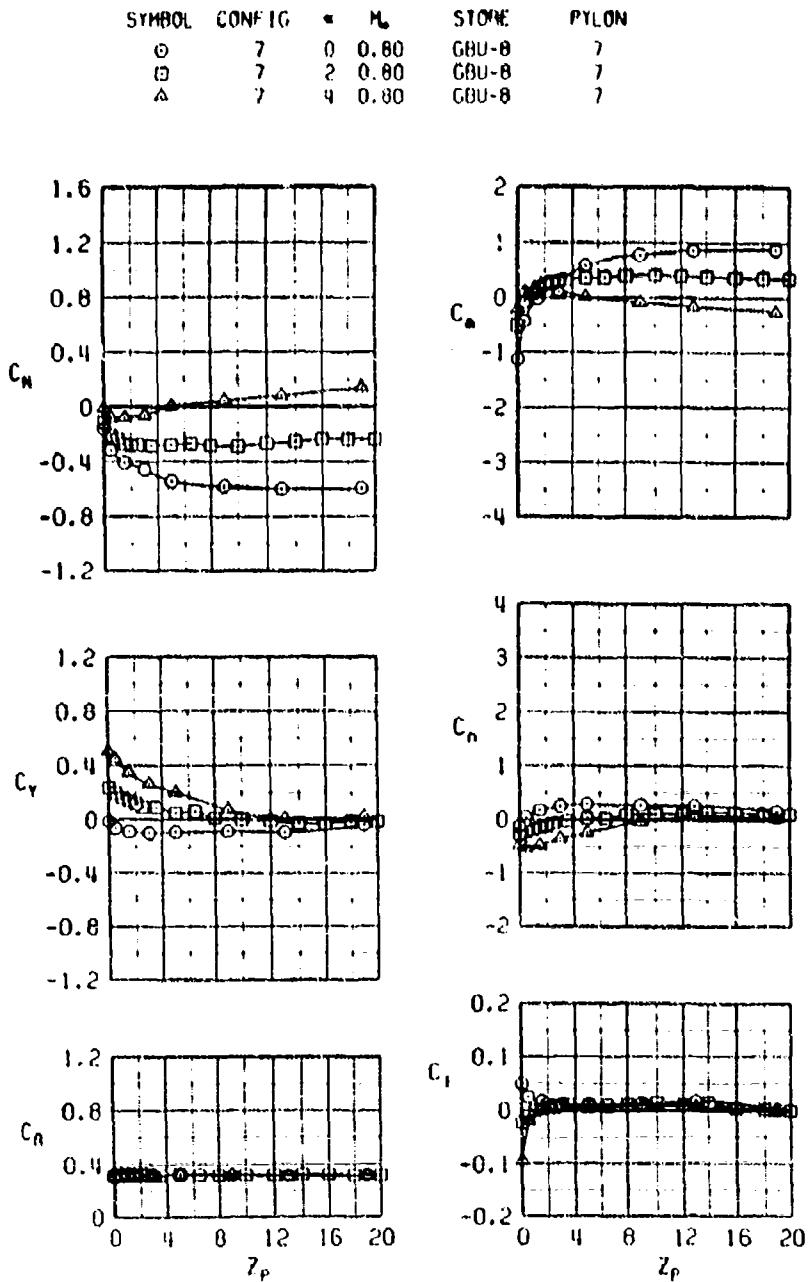


Figure 21. GBU-8 coefficient variation with aircraft angle of attack, configuration 7.

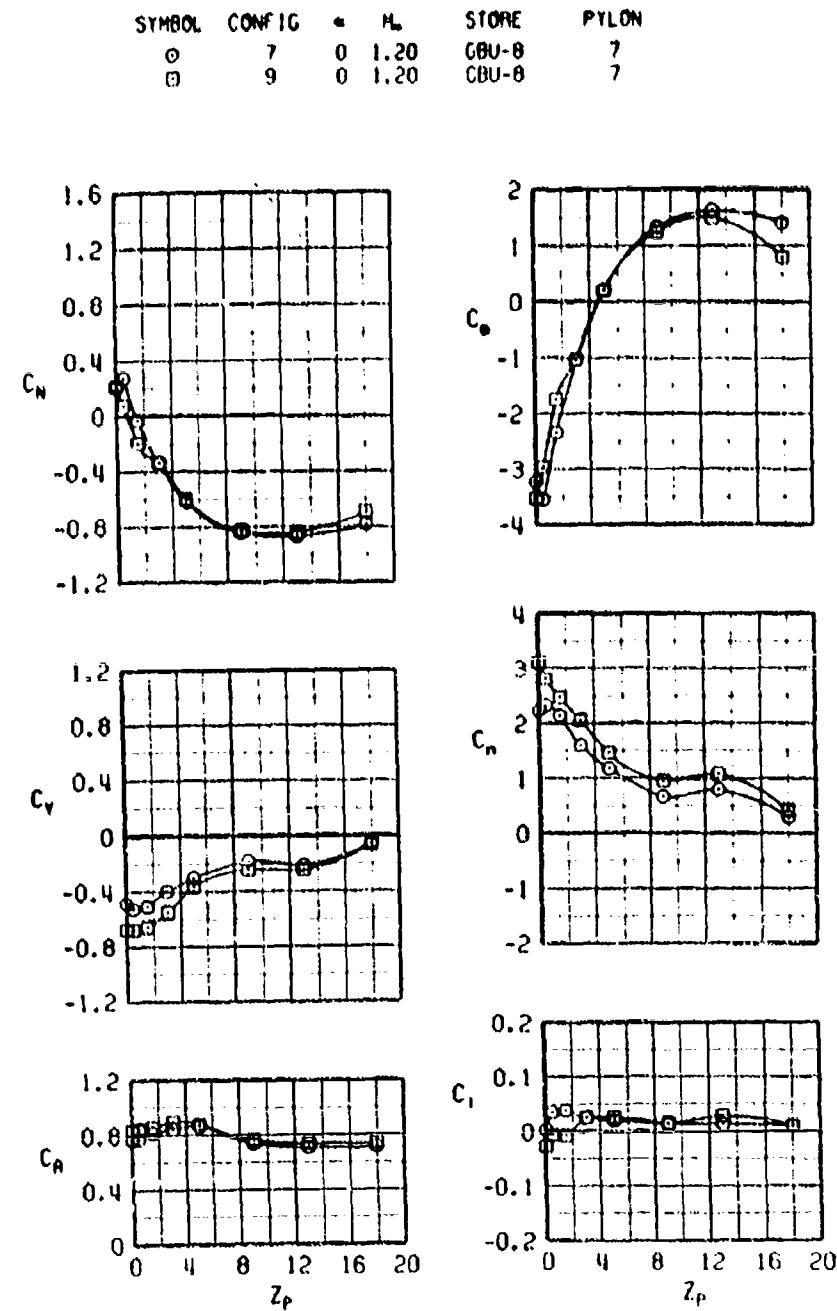


Figure 22. Effect of the addition of an inboard 370-gal fuel tank on the GBU-8, configurations 7 and 9.

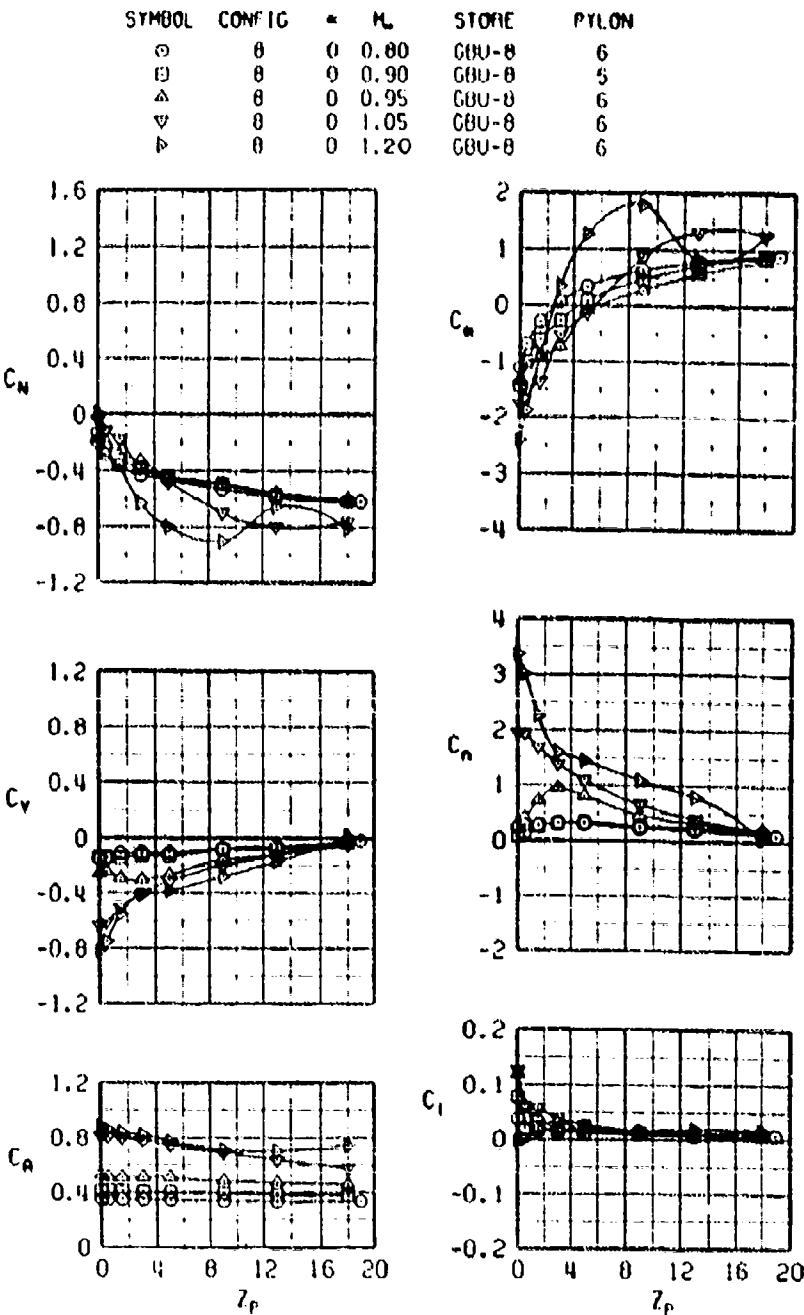


Figure 23. Aerodynamic characteristics of the GBU-8, configuration 8.

SYMBOL	CONF 10	α	M_∞	STOKE	PYLON	BACK
O	10	2	0.60	MK-82SE	2	1-1
O	10	2	0.80	MK-82SE	2	1-1
Δ	10	2	0.90	MK-82SE	2	1-1
∇	10	2	0.95	MK-82SE	2	1-1

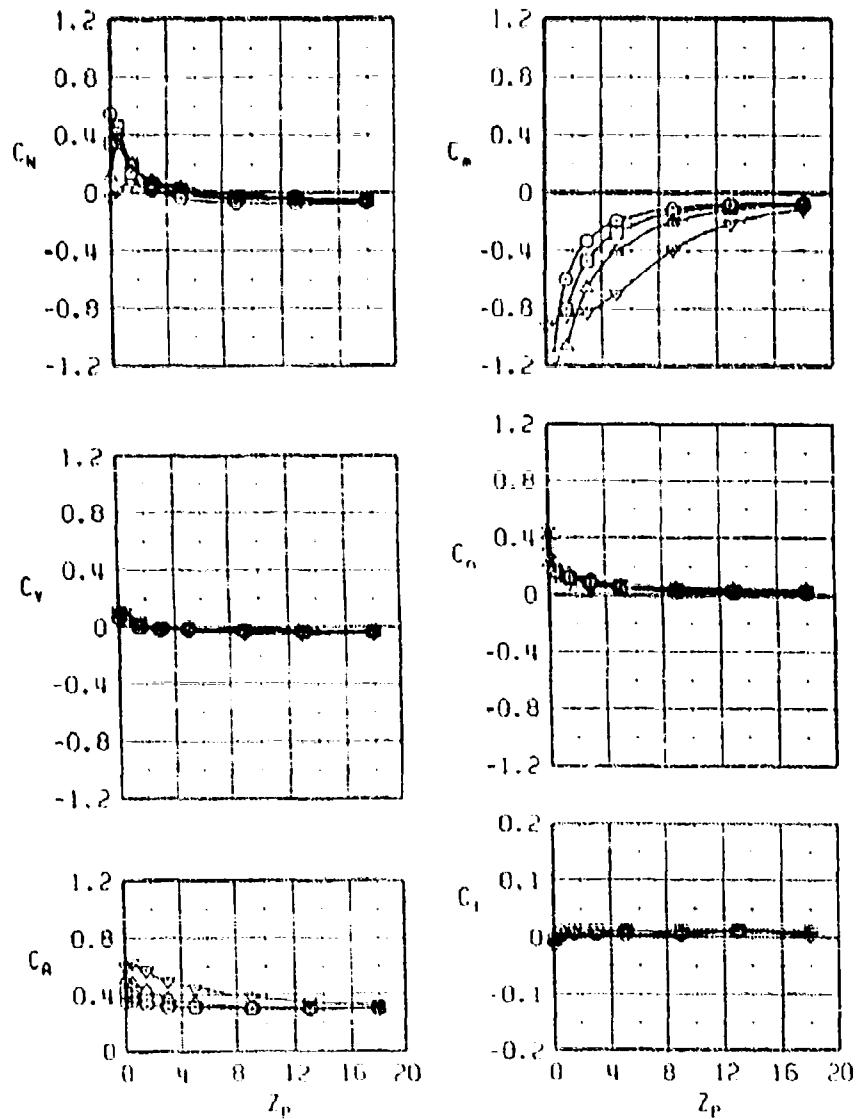


Figure 24. Aerodynamic characteristics of the MK-82SE, configuration 10.

SYMBOL	CONFIG	α	M_∞	STORE	PYLON	RACK
C	10	2	0.60	MK-82SE	7	1-1
		4	0.00	MK-82SE	7	1-1
		6	0.00	MK-82SE	7	1-1
V	10	10	0.00	MK-82SE	7	1-1

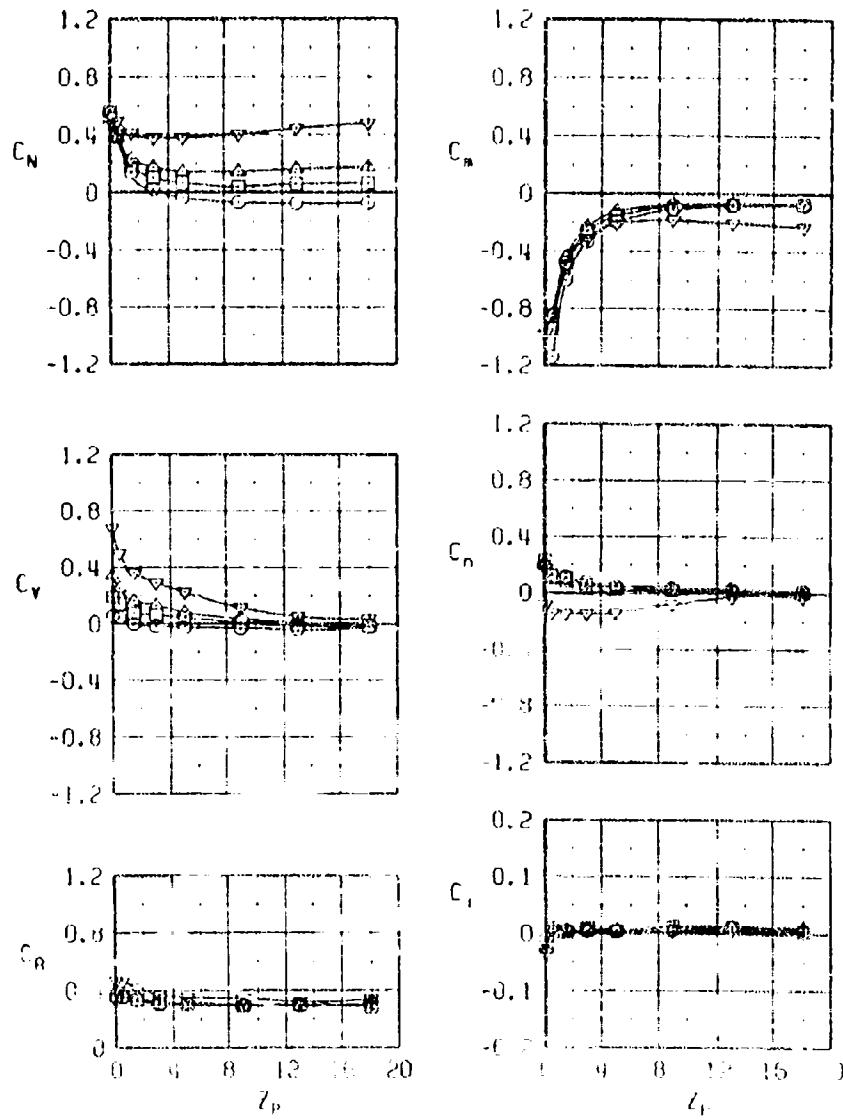
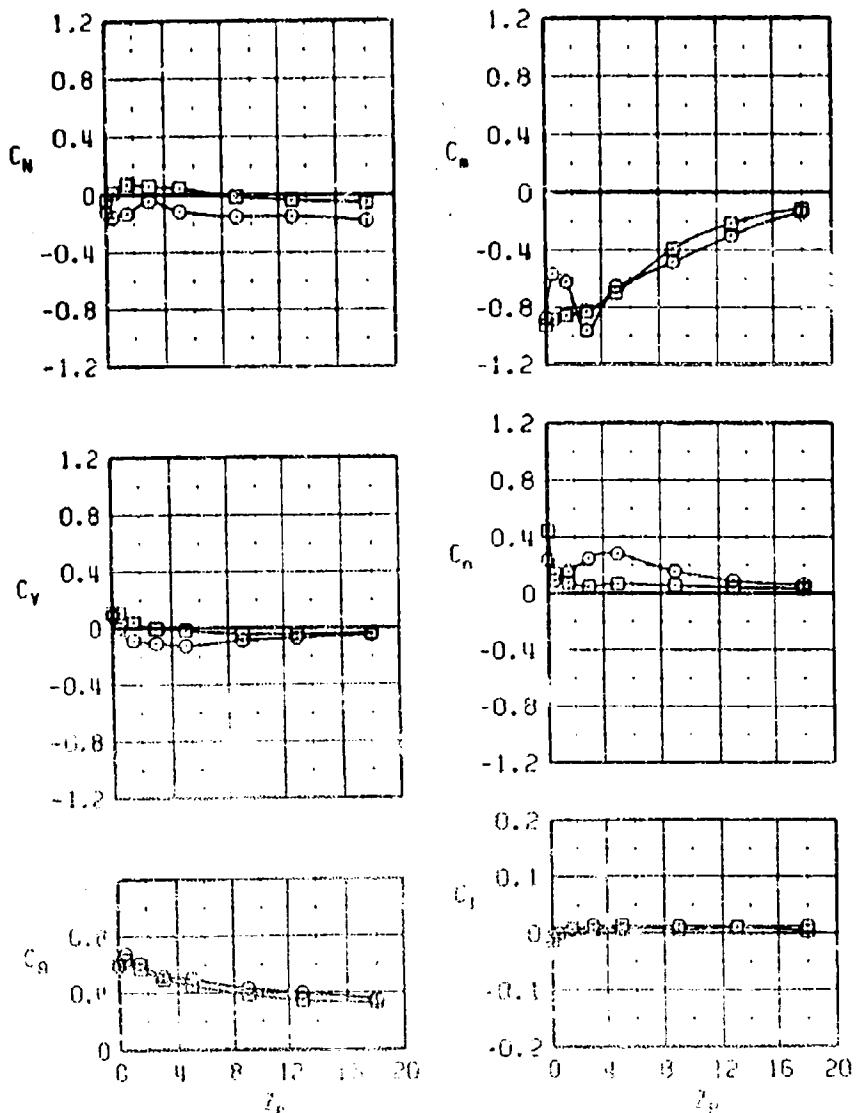
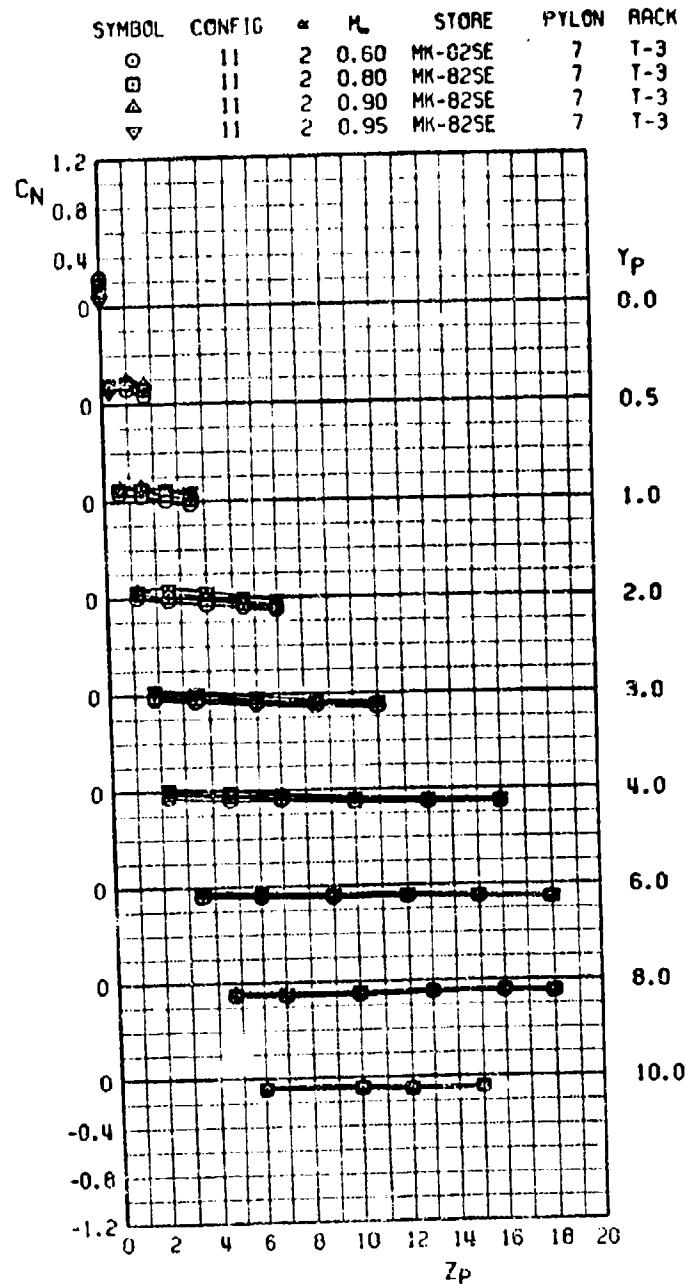
a. $M_\infty = 0.6$

Figure 25. MK-82SE coefficient variation with aircraft angle of attack, configuration 10.

SYMBOL	CONFIG	α	M_∞	STORE	PYLON	RACK
○	10	0	0.95	MR-82SE	7	T-1
□	10	2	0.95	MR-82SE	7	T-1

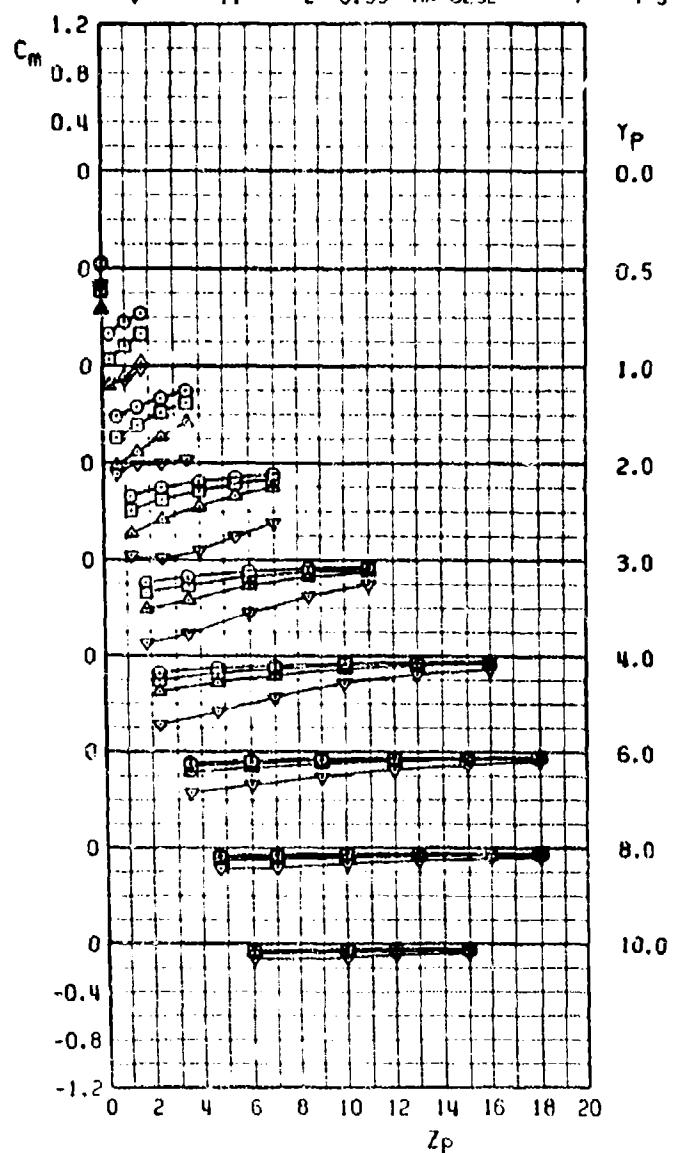


b. $M_\infty = 0.95$
Figure 25. Concluded.

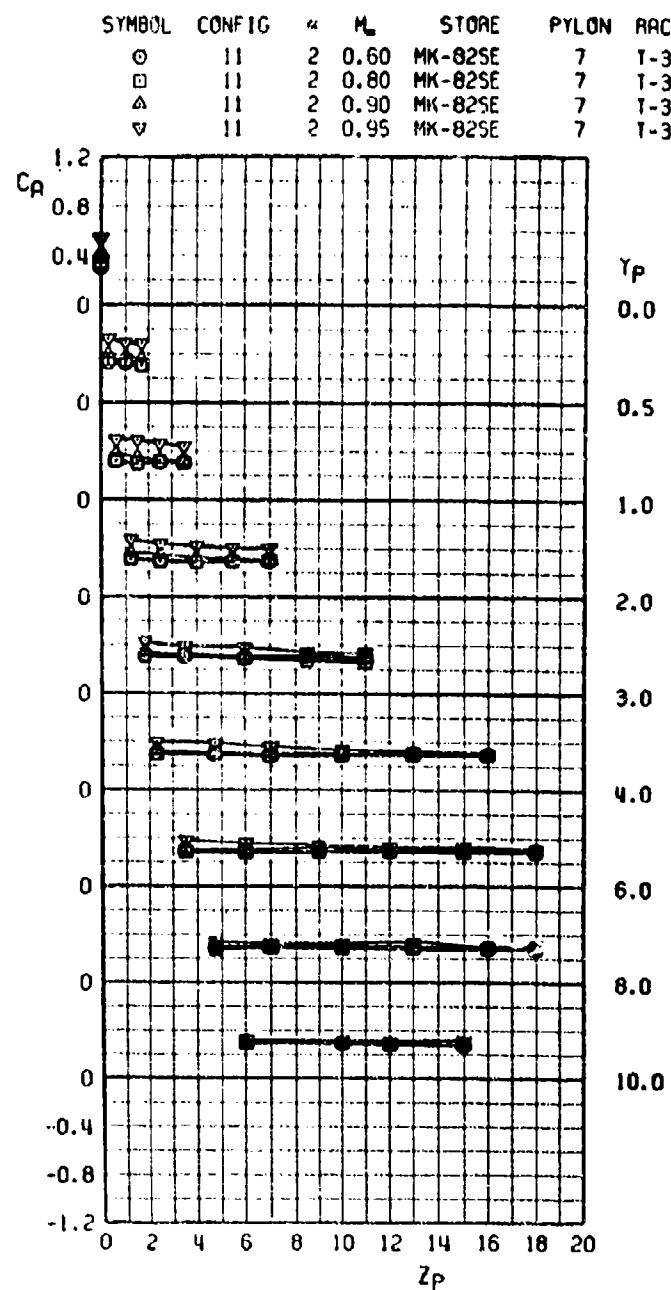


a. Normal-force coefficient
 Figure 26. Aerodynamic characteristics of the MK-82SE,
 configuration 11.

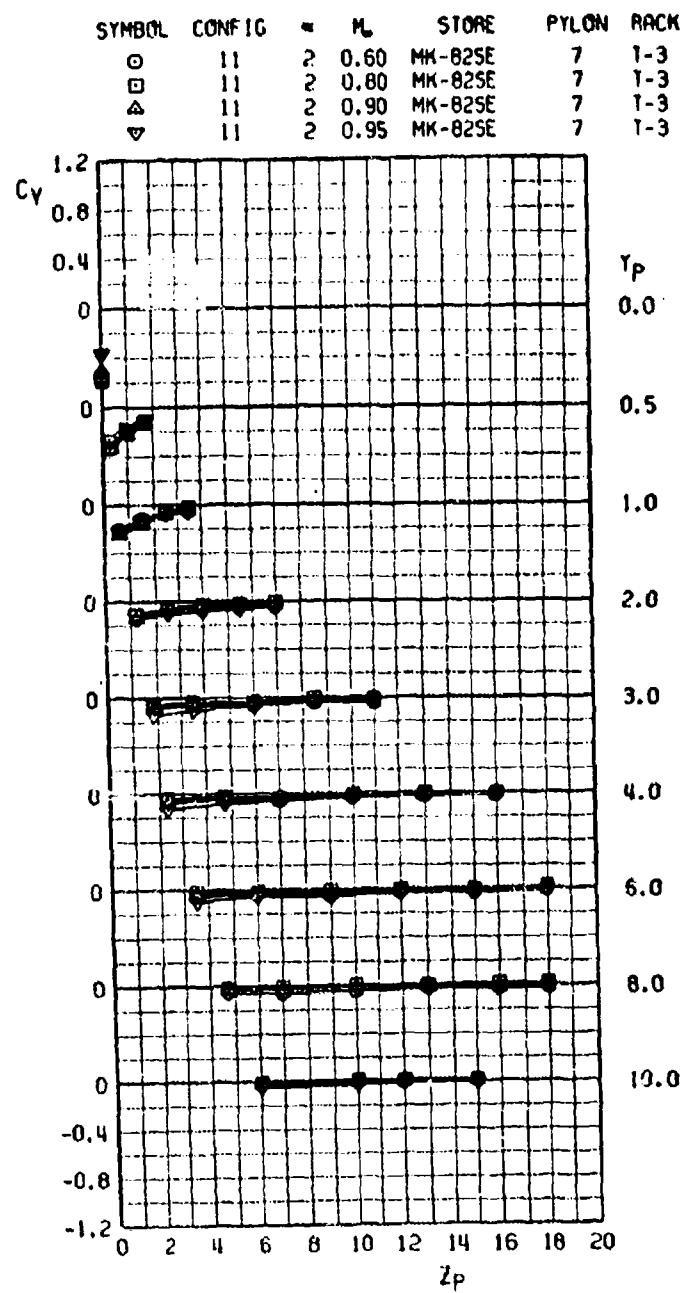
SYMBOL	CONFIG	α	M_∞	STORE	PYLON	RACK
○	II	2	0.60	MK-82SE	7	T-3
□	II	2	0.80	MK-82SE	7	T-3
△	II	2	0.90	MK-82SE	7	T-3
▽	II	2	0.95	MK-82SE	7	T-3



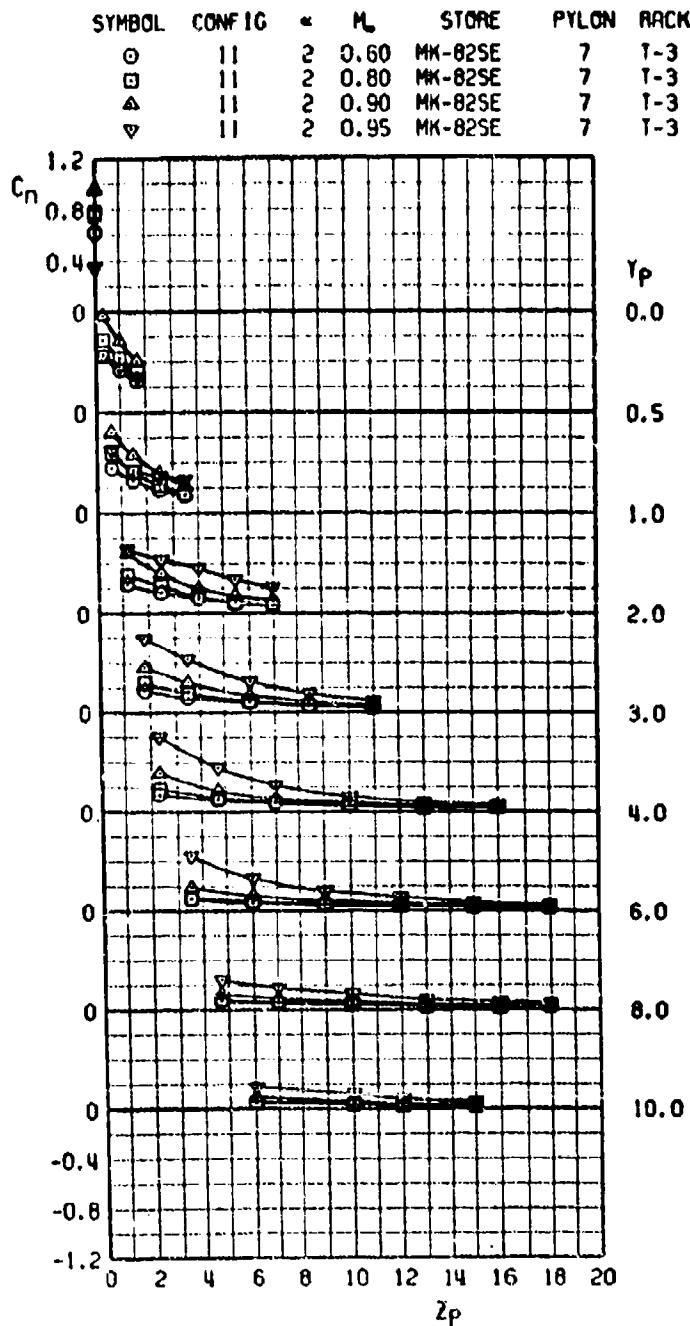
b. Pitching-moment coefficient
Figure 26. Continued.



c. Axial-force coefficient
Figure 26. Continued.



d. Side-force coefficient
Figure 26. Continued.



e. Yawing-moment coefficient
Figure 26. Concluded.

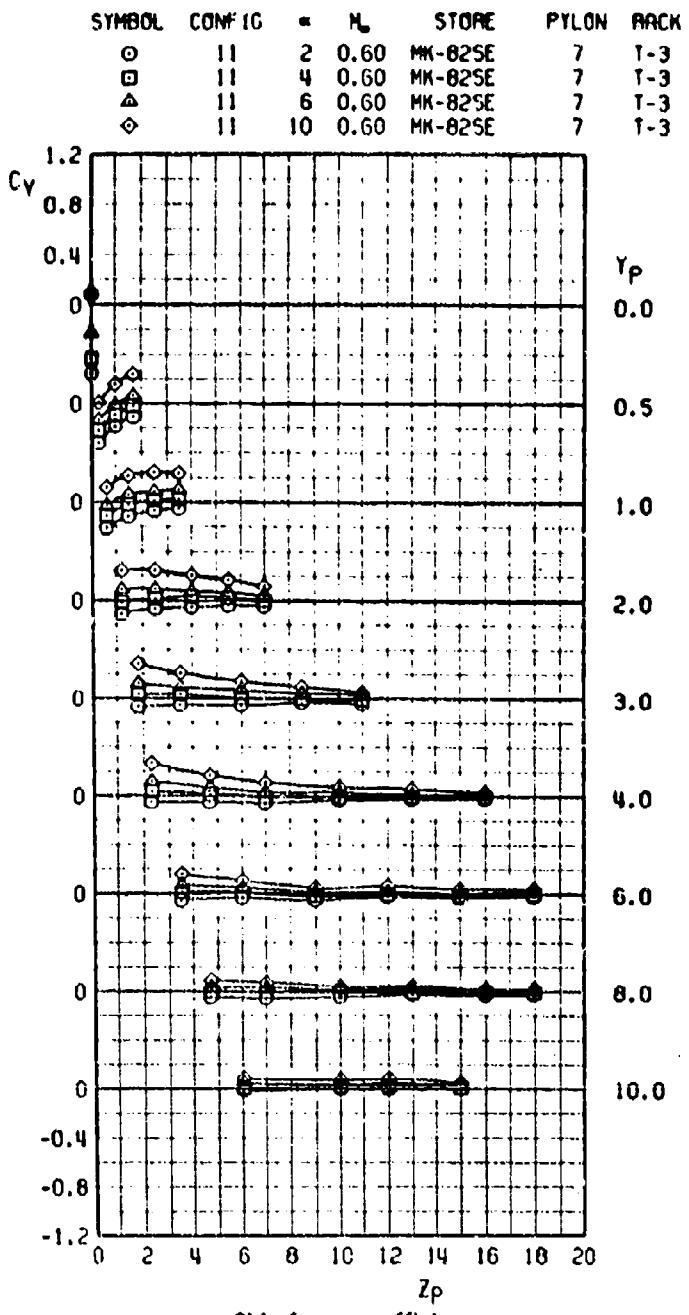
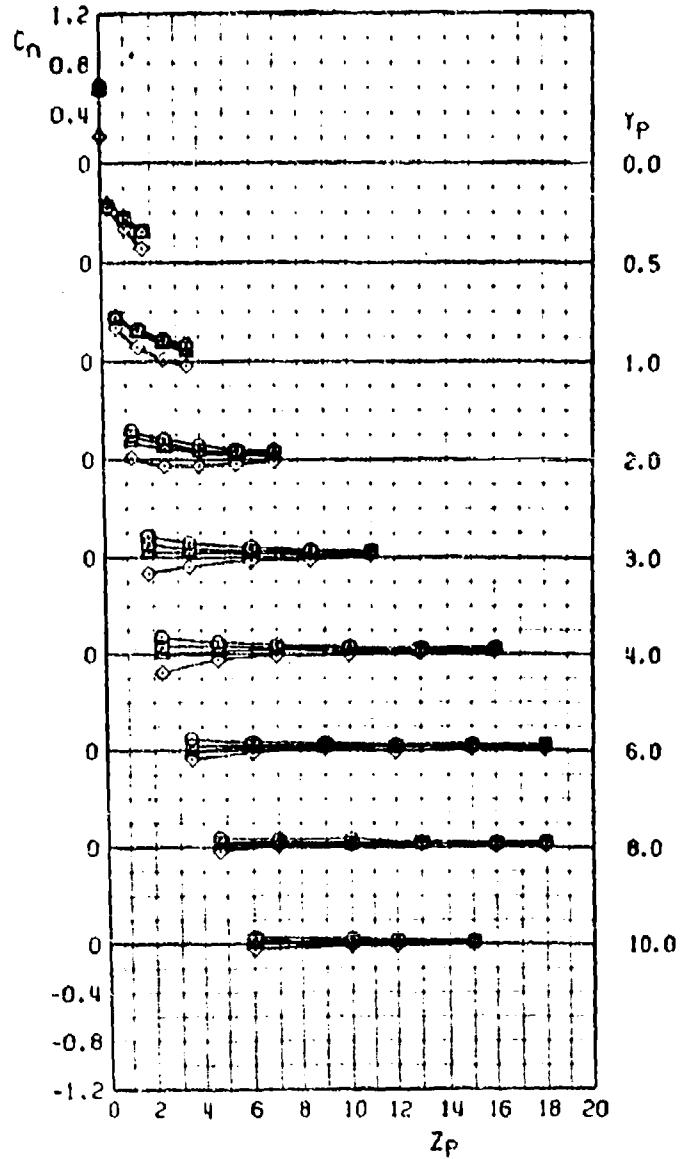


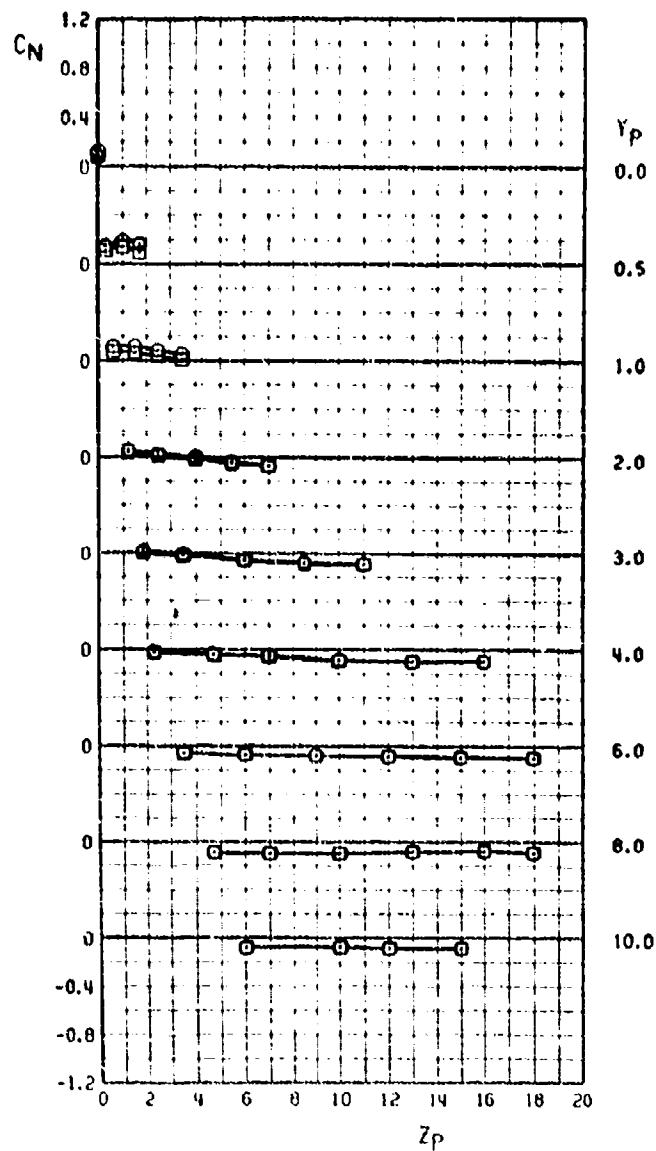
Figure 27. MK-82SE coefficient variation with aircraft angle of attack, configuration 11.

SYMBOL	CONFIG	α	M_∞	STORE	PYLON	RACK
○	11	2	0.60	MK-82SE	7	T-3
□	11	4	0.60	MK-82SE	7	T-3
△	11	6	0.60	MK-82SE	7	T-3
◊	11	10	0.60	MK-82SE	7	T-3



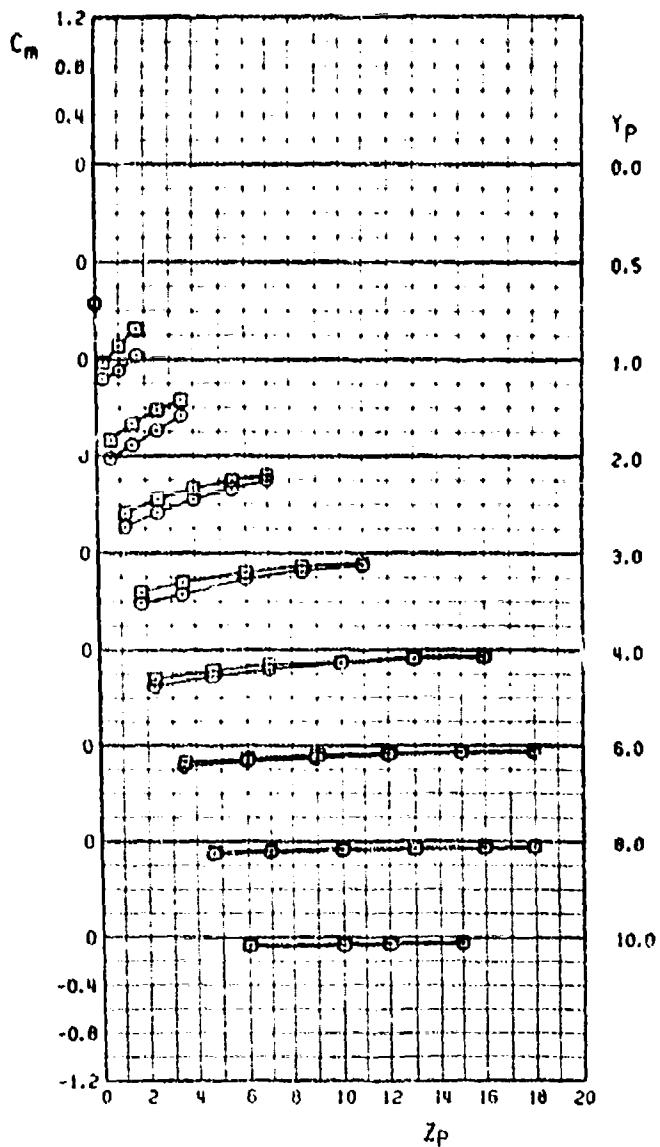
b. Yawing-moment coefficient
Figure 27. Concluded.

SYMBOL	CONFIG	M_∞	STORE	PYLON	RACK	
○	11	2	0.90	MK-82SE	?	1-3
□	13	2	0.90	MK-82SE	?	1-3



a. Normal-force coefficient, $M_\infty = 0.9$
Figure 28. Effect of an adjacent store on the MK-82SE, configurations 11 and 13.

SYMBOL	CONFIG	M_∞	STORE	PYLON	RACK	
○	11	2	0.90	MM-82SE	7	1-3
□	13	2	0.90	MM-82SE	7	1-3



b. Pitching-moment coefficient, $M_\infty = 0.9$
Figure 28. Continued.

SYMBOL	CONFIG	α	M_∞	STORE	PYLON	RACK
○	11	2	0.95	MK-82SE	7	T-3
□	13	2	0.95	MK-82SE	7	T-3

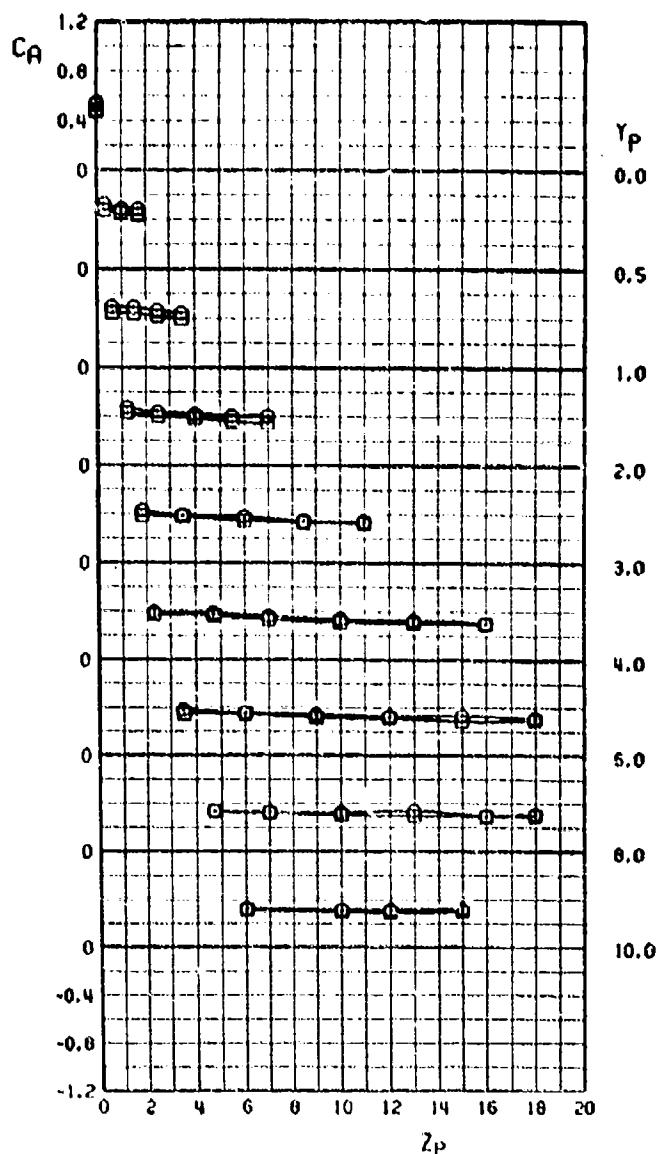
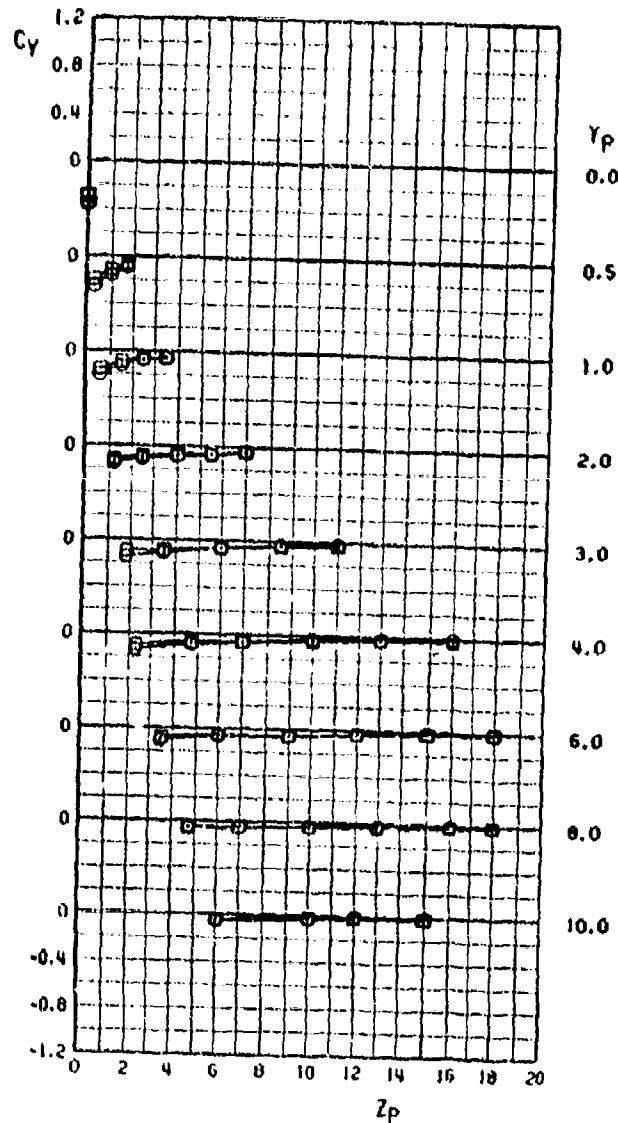
c. Axial-force coefficient, $M_\infty = 0.95$

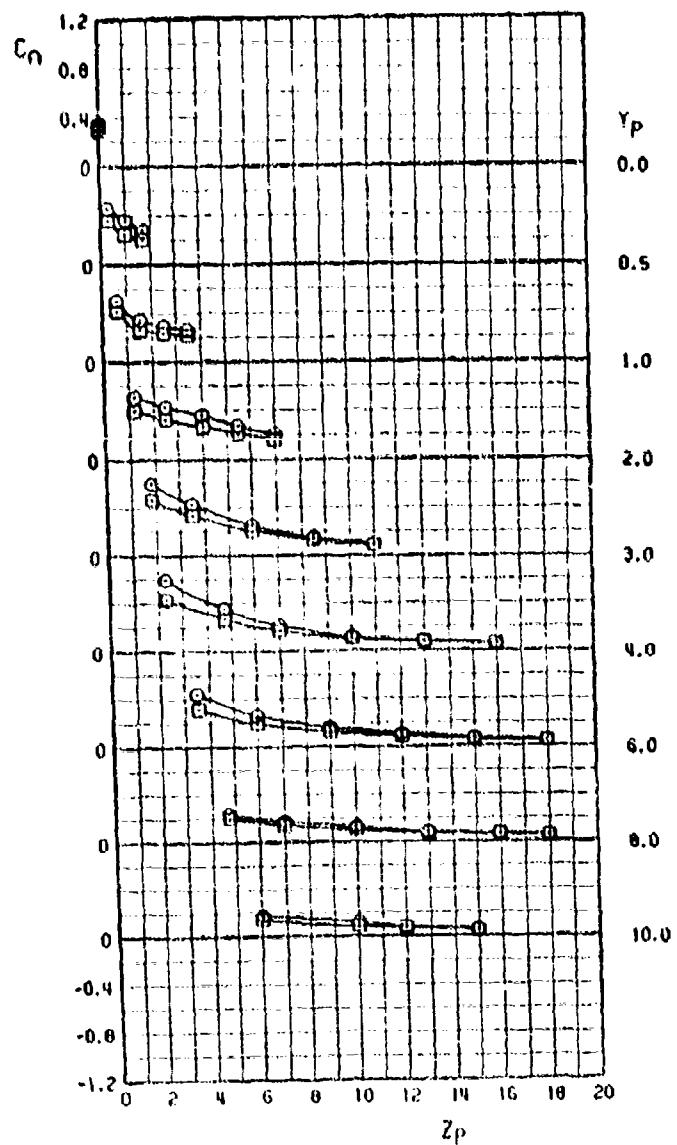
Figure 28. Continued.

SYMBOL	CONFIG	α	M_∞	STORE	PYLON	RACK
○	11	2	0.95	MK-82SE	7	T-3
□	13	2	0.95	MK-82SE	7	T-3

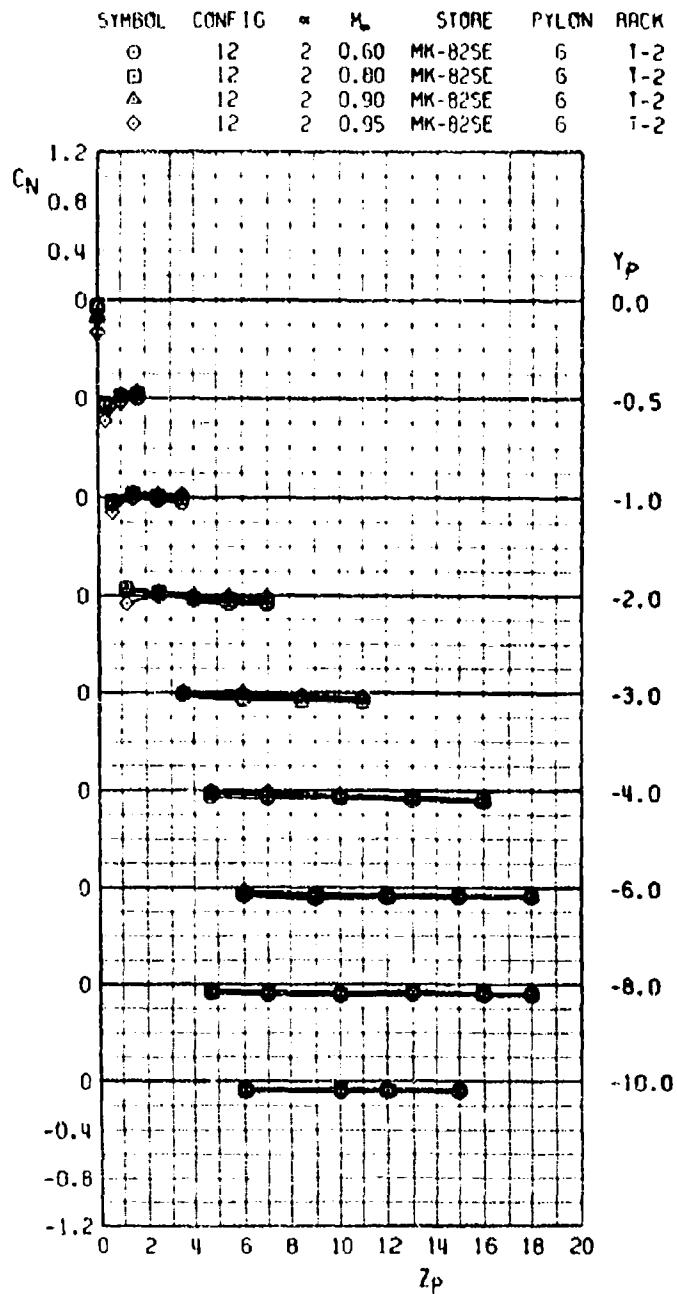


d. Side-force coefficient, $M_\infty = 0.95$
Figure 28. Continued.

SYMBOL	CONFIG	α	M_∞	STORE	PYLON	RACK
○	11	2	0.95	MK-82SE	7	T-3
□	13	2	0.95	MK-82SE	7	T-3



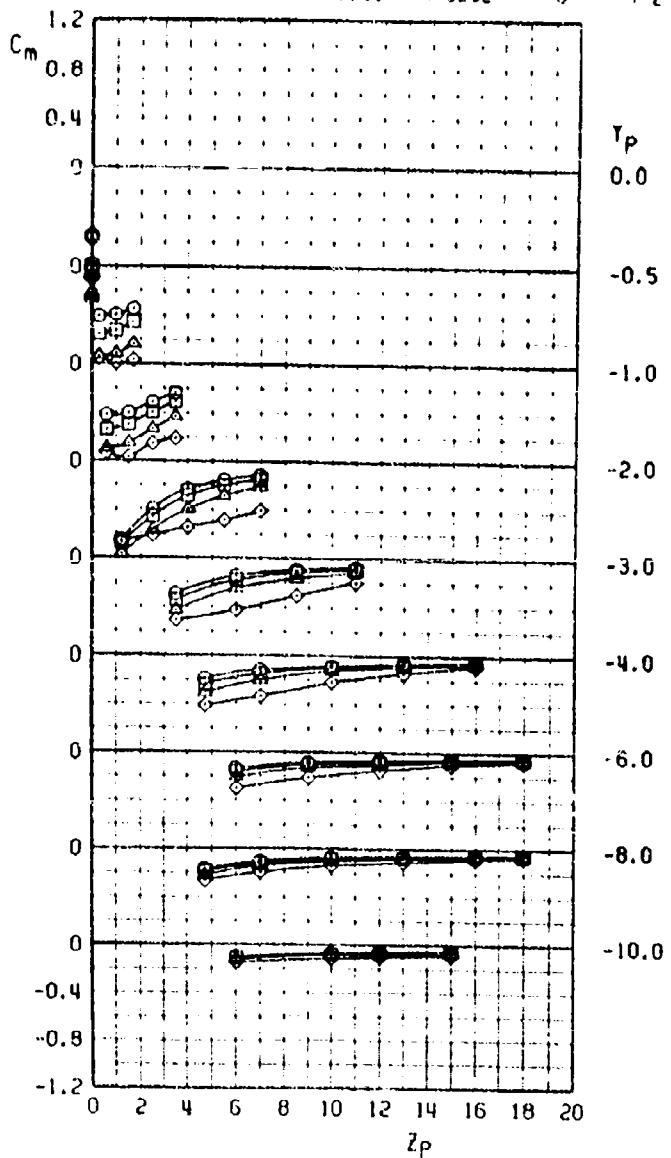
e. Yawing-moment coefficient, $M_\infty = 0.95$
Figure 28. Concluded.



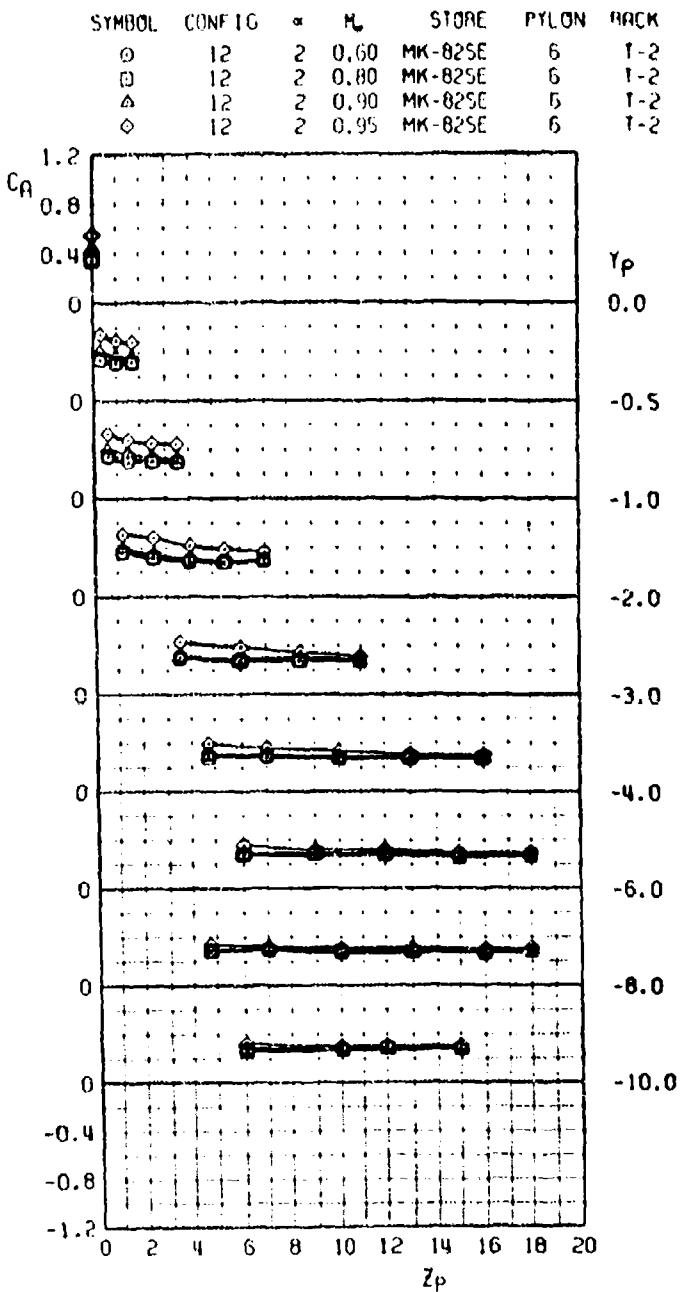
a. Normal-force coefficient

Figure 29. Aerodynamic characteristics of the MK-82SE, configuration 12.

SYMBOL	CONFIG	α	M	STORE	PYLON	RACK
○	12	2	0.60	MK-82SE	6	T-2
□	12	2	0.80	MK-82SE	6	T-2
△	12	2	0.90	MK-82SE	6	T-2
◊	12	2	0.95	MK-82SE	6	T-2

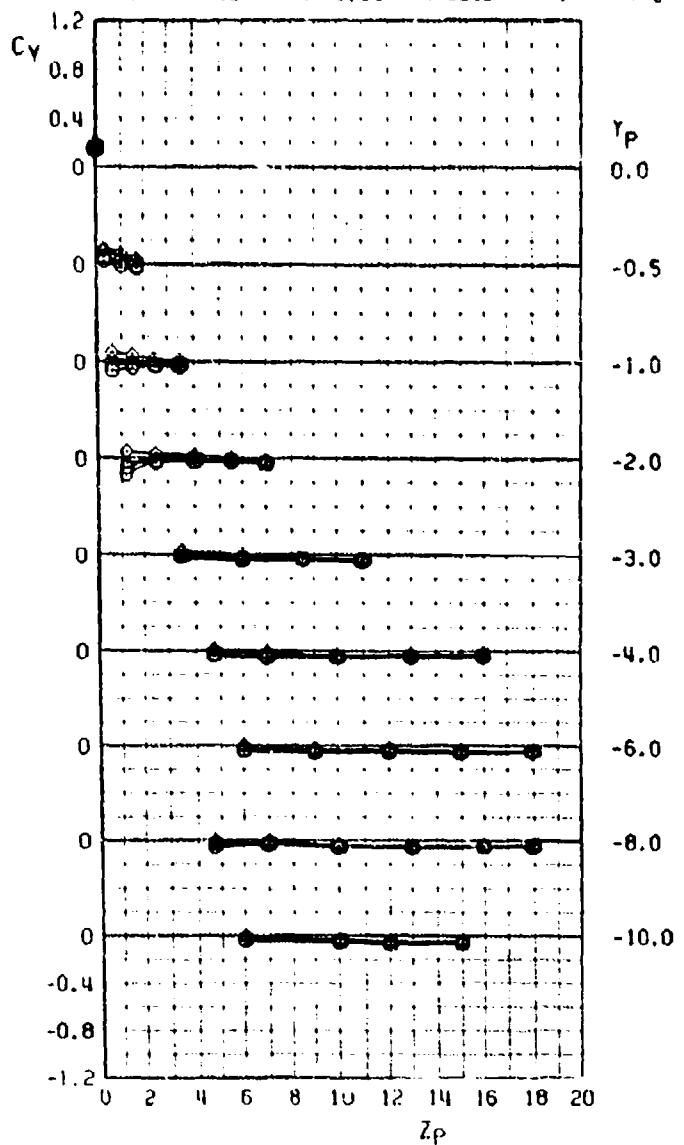


b. Pitching-moment coefficient
Figure 29. Continued.



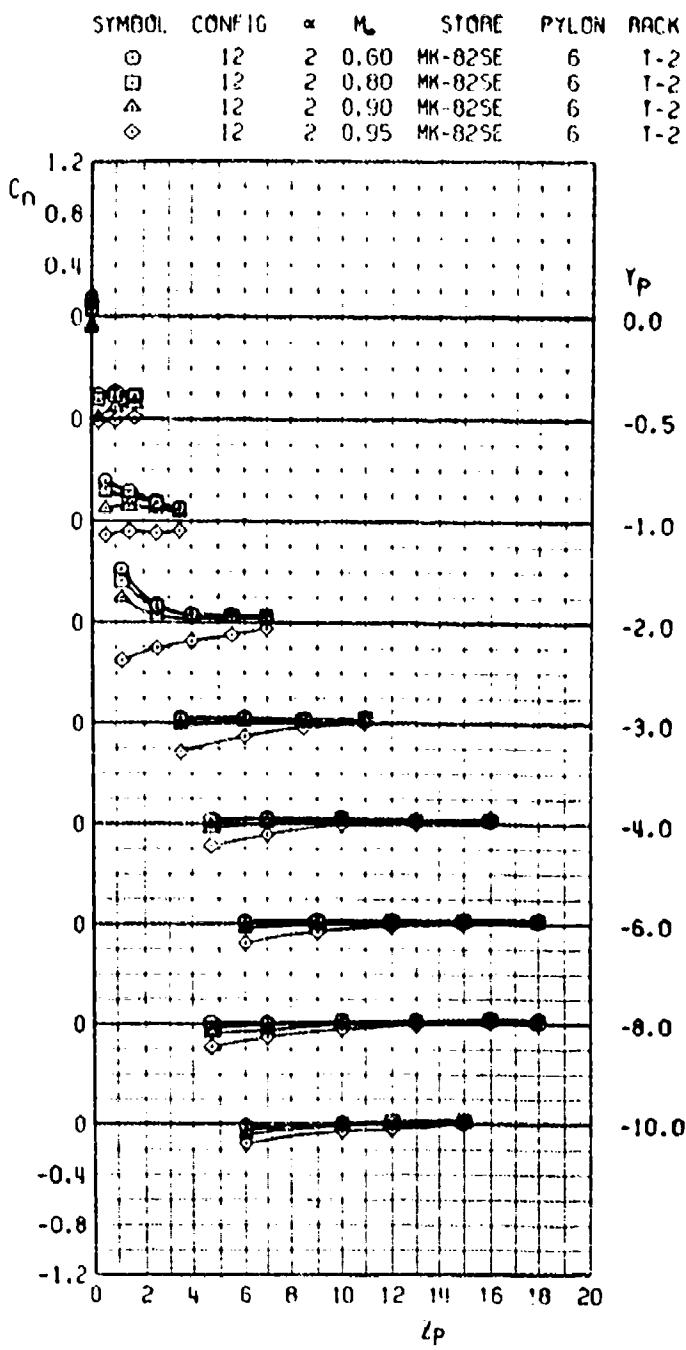
c. Axial-force coefficient
Figure 29. Continued.

SYMBOL	CONFIG	α	M _∞	STORE	PYLON	RACK
○	12	2	0.60	MK-82SE	6	T-2
□	12	2	0.00	MK-82SE	6	T-2
△	12	2	0.90	MK-82SE	6	T-2
◊	12	2	0.95	MK-82SE	6	T-2

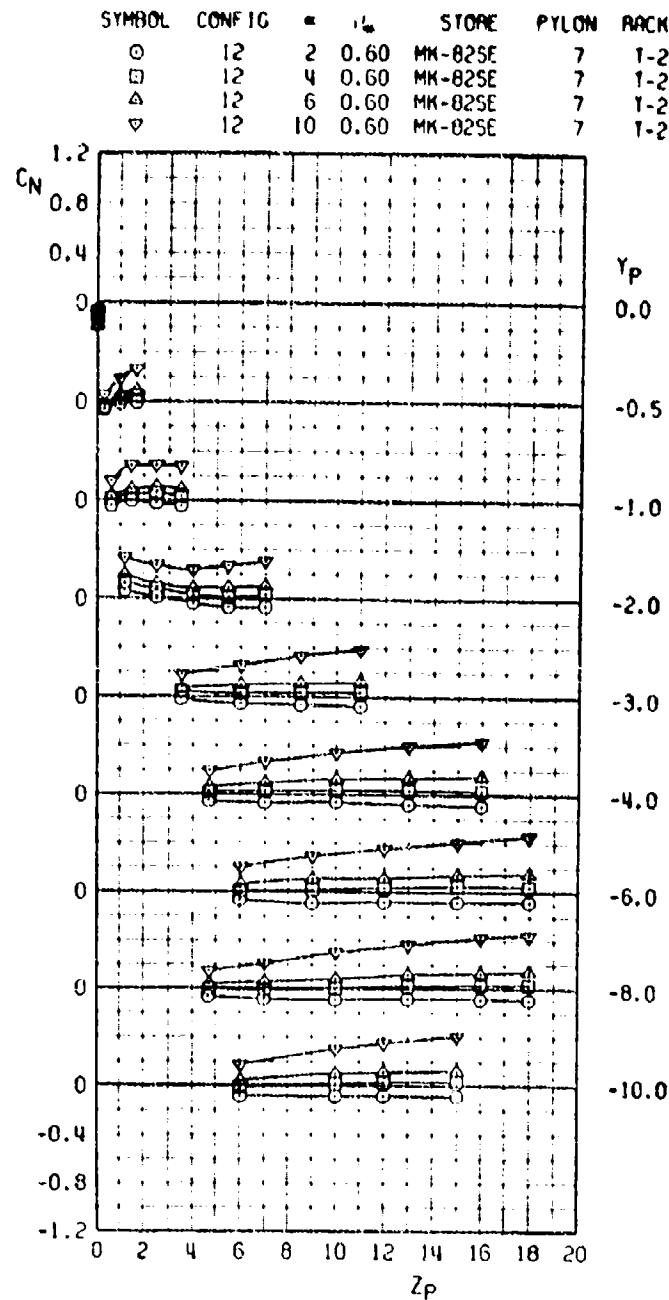


d. Side-force coefficient

Figure 29. Continued.



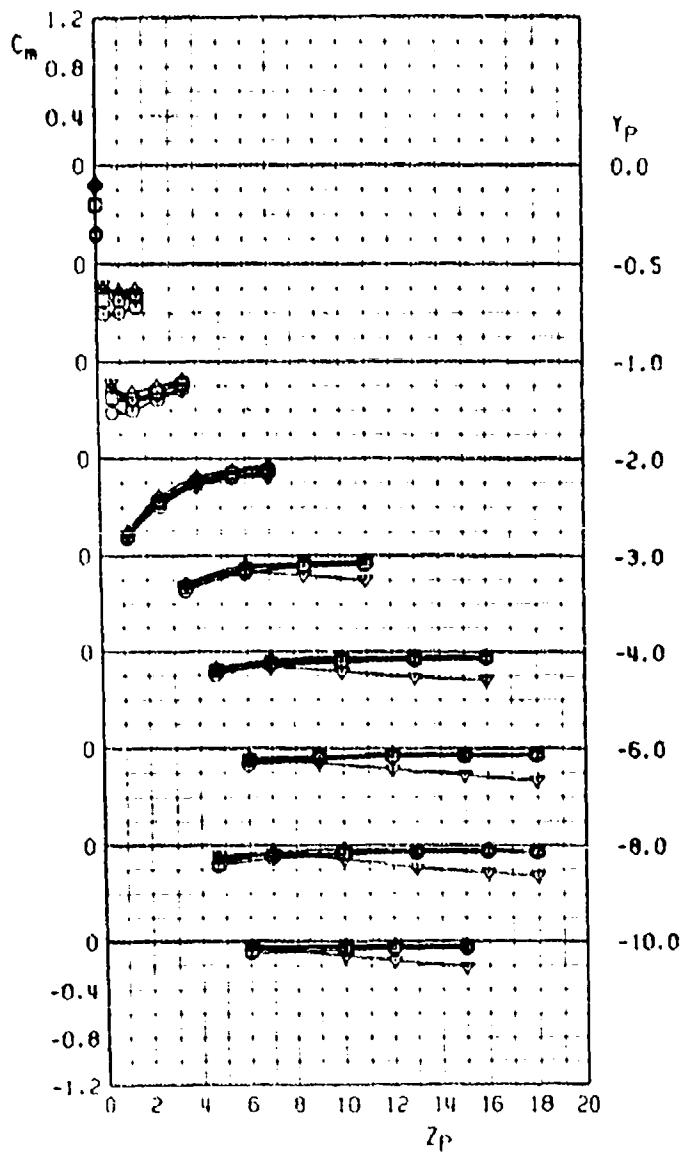
e. Yawing-moment coefficient
Figure 29. Concluded.



a. Normal-force coefficient

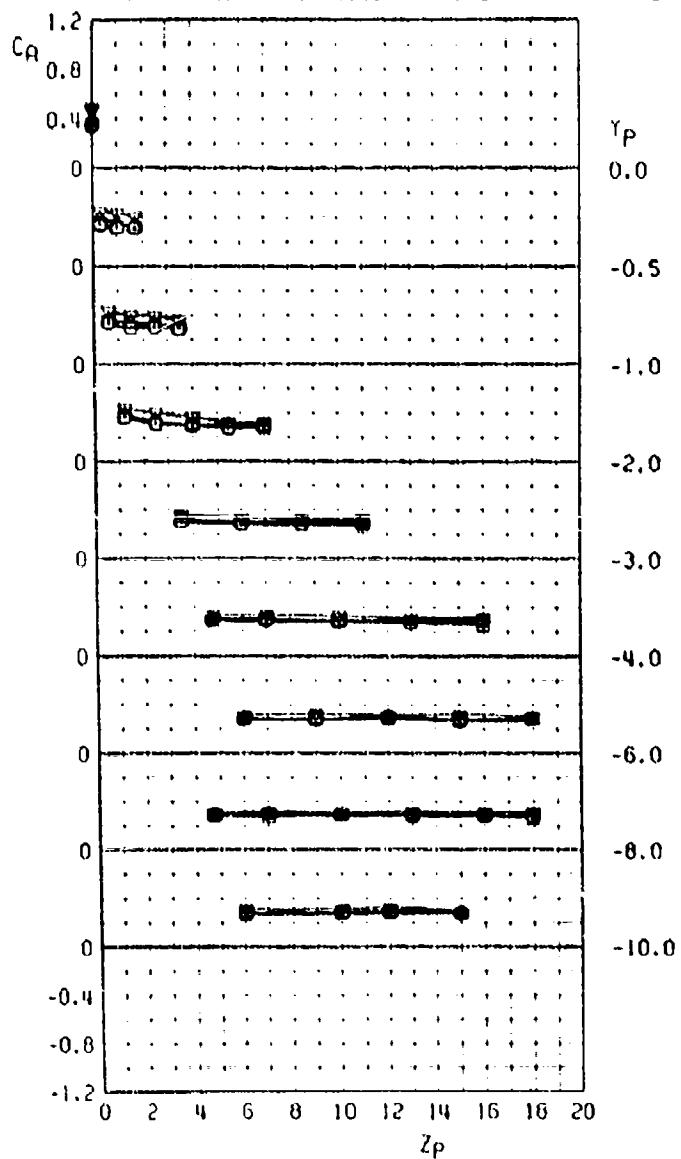
Figure 30. MK-82SE coefficient variation with aircraft angle of attack, configuration 12.

SYMBOL	CONFIG	\bullet	M_∞	STORE	PYLON	RACK
○	12	2	0.60	MK-82SE	7	1-2
□	12	4	0.60	MK-62SE	7	1-2
△	12	6	0.60	MK-82SE	7	1-2
▽	12	10	0.60	MK-82SE	7	1-2



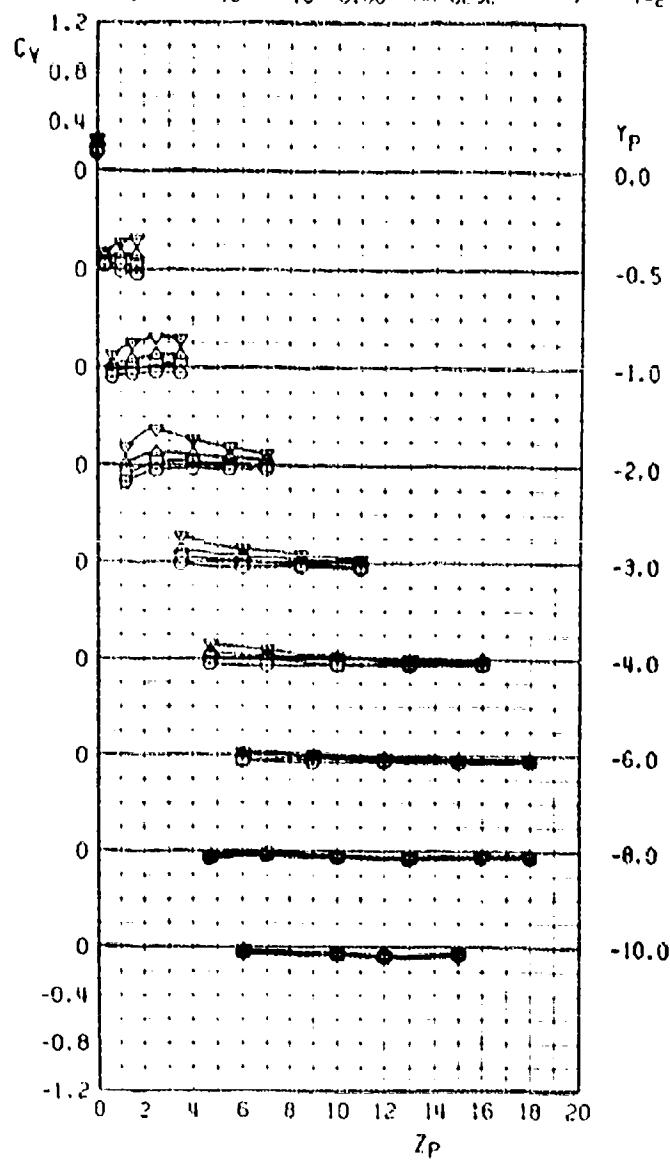
b. Pitching-moment coefficient
Figure 30. Continued.

SYMBOL	CONFIG	M_∞	STORE	PTLN	RACK	
O	12	2	0.60	MK-02SE	7	T-2
□	12	4	0.60	MK-02SE	7	T-2
△	12	6	0.60	MK-02SE	7	T-2
▽	12	10	0.60	MK-02SE	7	T-2



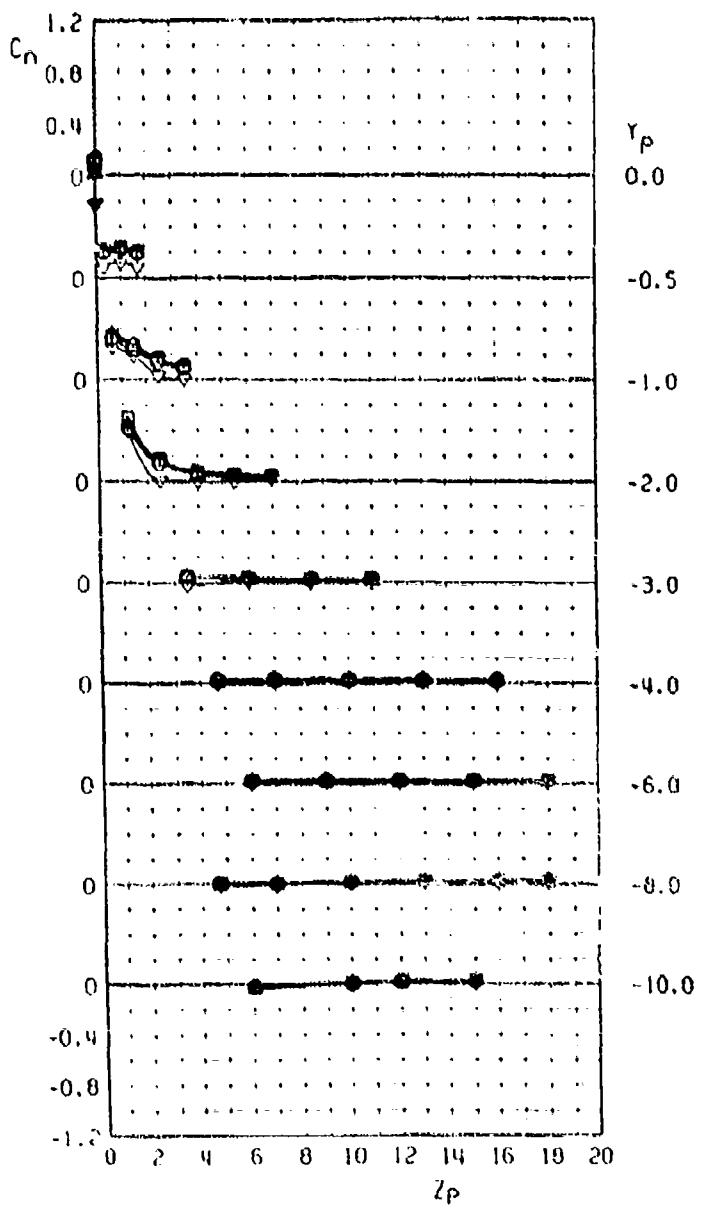
c. Axial-force coefficient
Figure 30. Continued.

SYMBOL	CONFIG	α	M_∞	STORE	PYLON	ROCK
○	12	2	0.60	MK-82SE	7	T-2
□	12	4	0.60	MK-82SE	7	T-2
△	12	6	0.60	MK-82SE	7	T-2
▽	12	10	0.60	MK-82SE	7	T-2



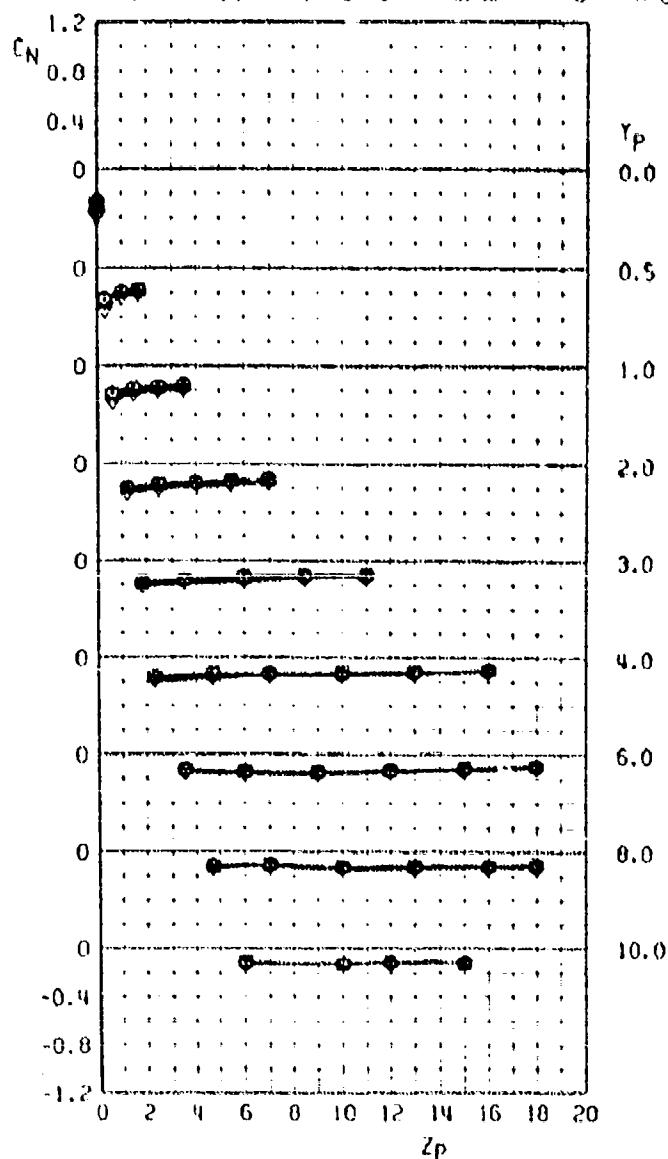
d. Side-force coefficient
Figure 30. Continued.

SYMBOL	CONFIG	#	M ₀	STORE	PYLON	RACK
○	12	2	0.60	MM-B2SE	7	T-2
□	12	4	0.60	MR-B2SE	7	T-2
△	12	6	0.60	MR-B2SE	7	T-2
▽	12	10	0.60	MR-B2SE	7	T-2



e. Yawing-moment coefficient
Figure 30. Concluded.

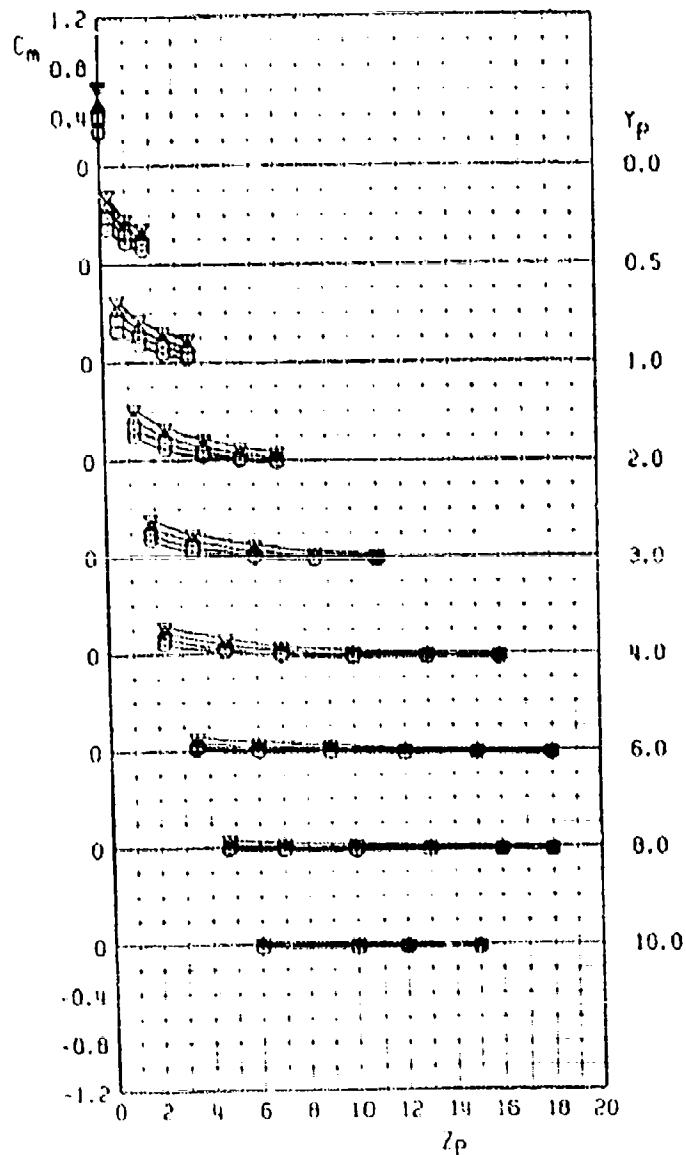
SYMBOL	CONFIG	μ	STORE	PTL ON	BACK
O	14	2	0.60	MK-82SE	6
O	14	2	0.80	MK-82SE	6
A	14	2	0.90	MK-82SE	6
V	14	2	0.95	MK-82SE	6



a. Normal-force coefficient

Figure 31. Aerodynamic characteristics of the MK-82SE,
configuration 14.

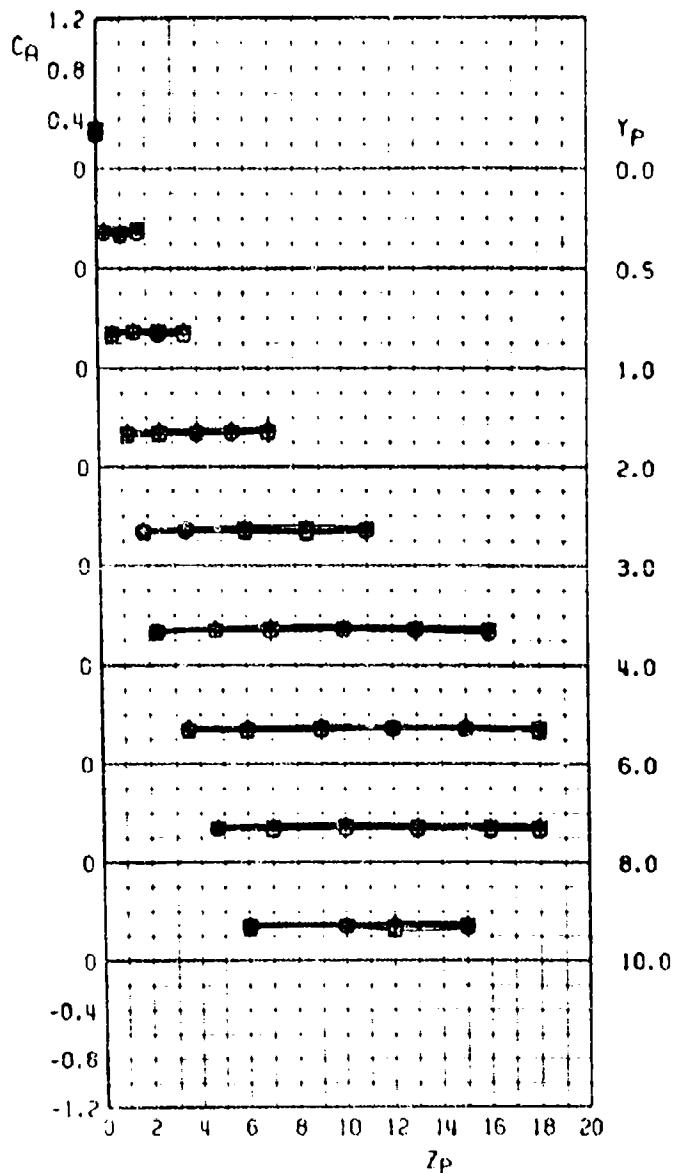
SYMBOL	CONFIG	α	H_L	STONE	PYLON	RACK
O	14	2	0.60	MK-02SE	6	M-G
O	14	2	0.80	MK-02SE	6	M-G
△	14	2	0.90	MK-02SE	6	M-G
▽	14	2	0.95	MK-02SE	6	M-G



b. Pitching-moment coefficient

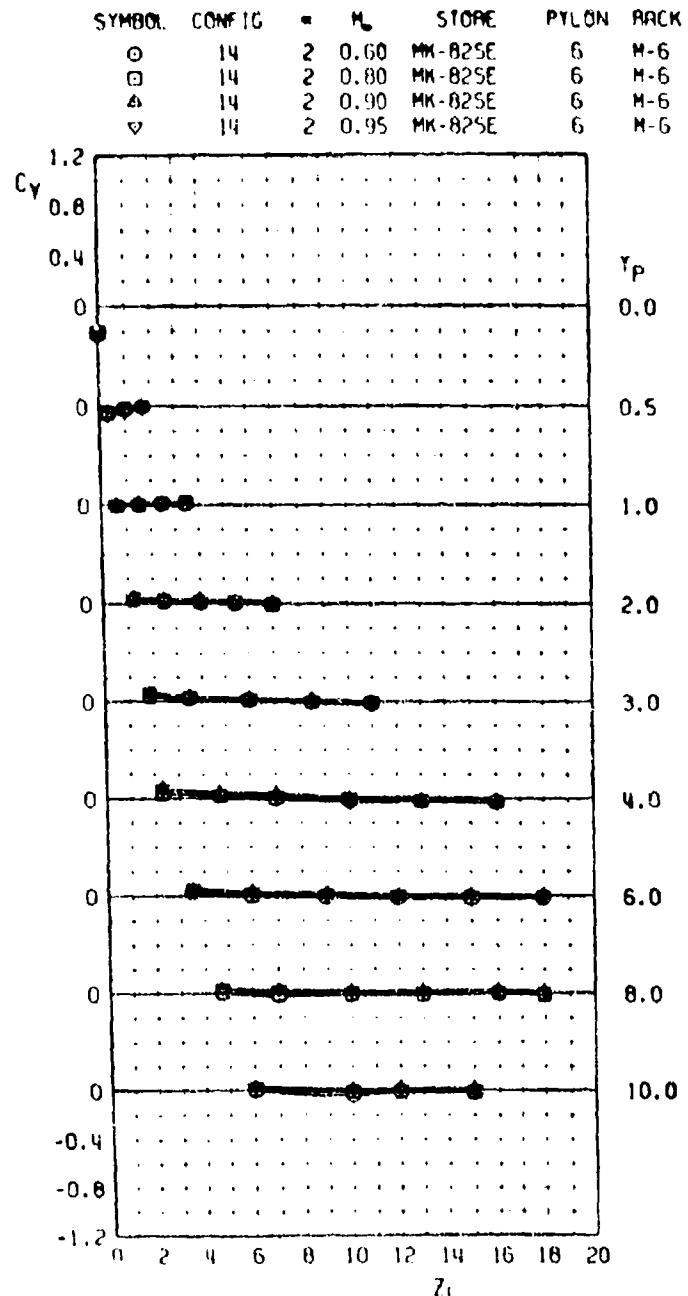
Figure 31. Continued.

SYMBOL	CONFIG	α	M_∞	STORE	PYLON	RACK
○	14	2	0.60	MR-82SE	6	M-G
□	14	2	0.80	MR-82SE	6	M-G
△	14	2	0.90	MR-82SE	6	M-G
▽	14	2	0.95	MR-82SE	6	M-G



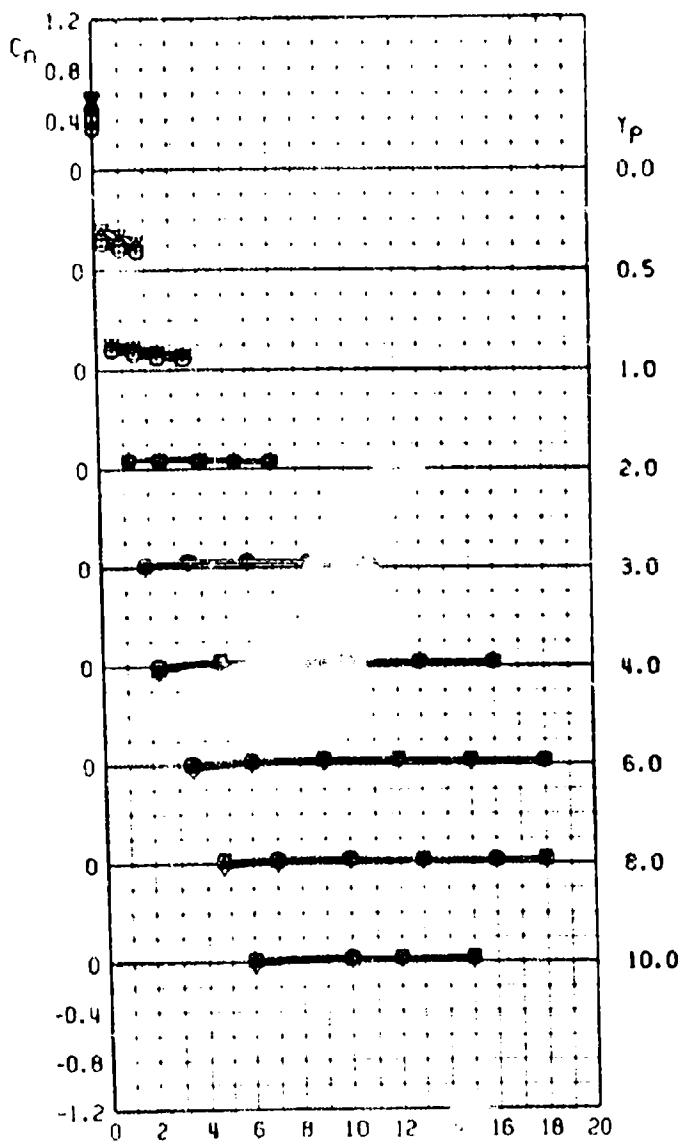
c. Axial-force coefficient

Figure 31. Continued.



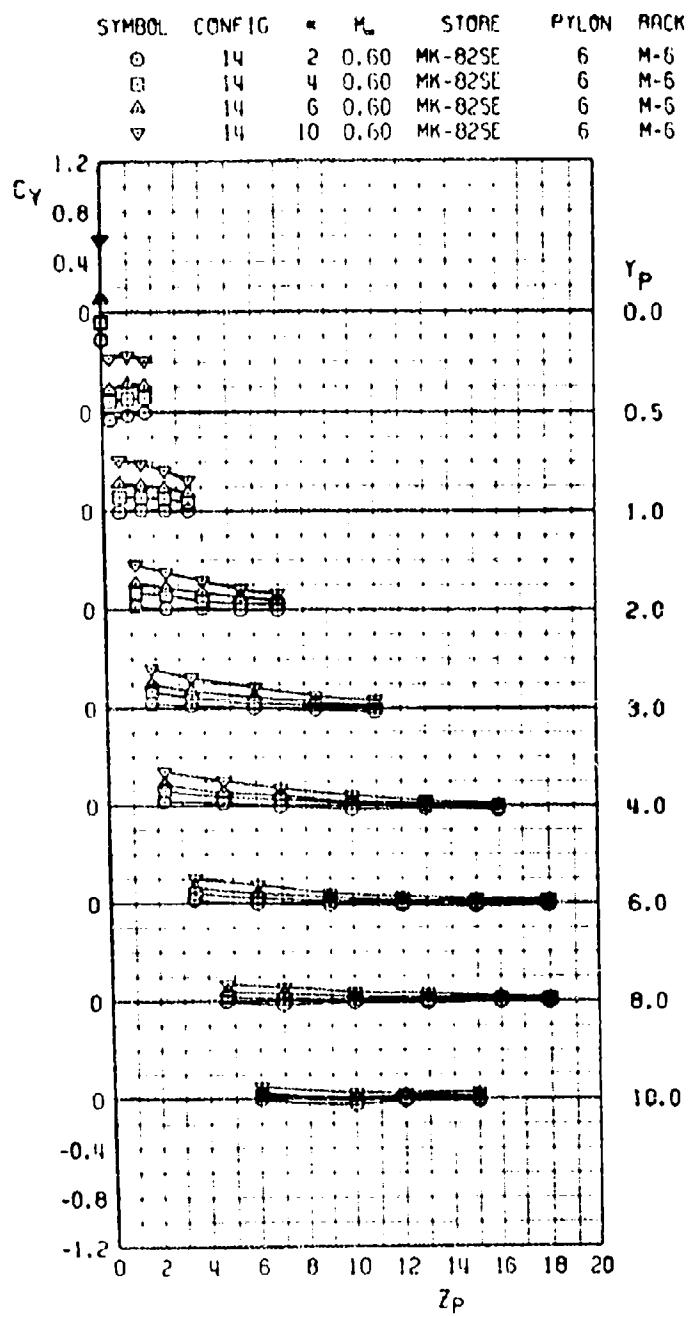
d. Side-force coefficient
Figure 31. Continued.

SYMBOL	CONFIG	α	M	STORE	PTYLON	RACK
○	14	2	0.60	MK-B2SE	6	M-6
□	14	2	0.80	MK-B2SE	6	M-6
△	14	2	0.90	MK-B2SE	6	M-6
▽	14	2	0.95	MK-B2SE	6	M-6



e. Yawing-moment coefficient

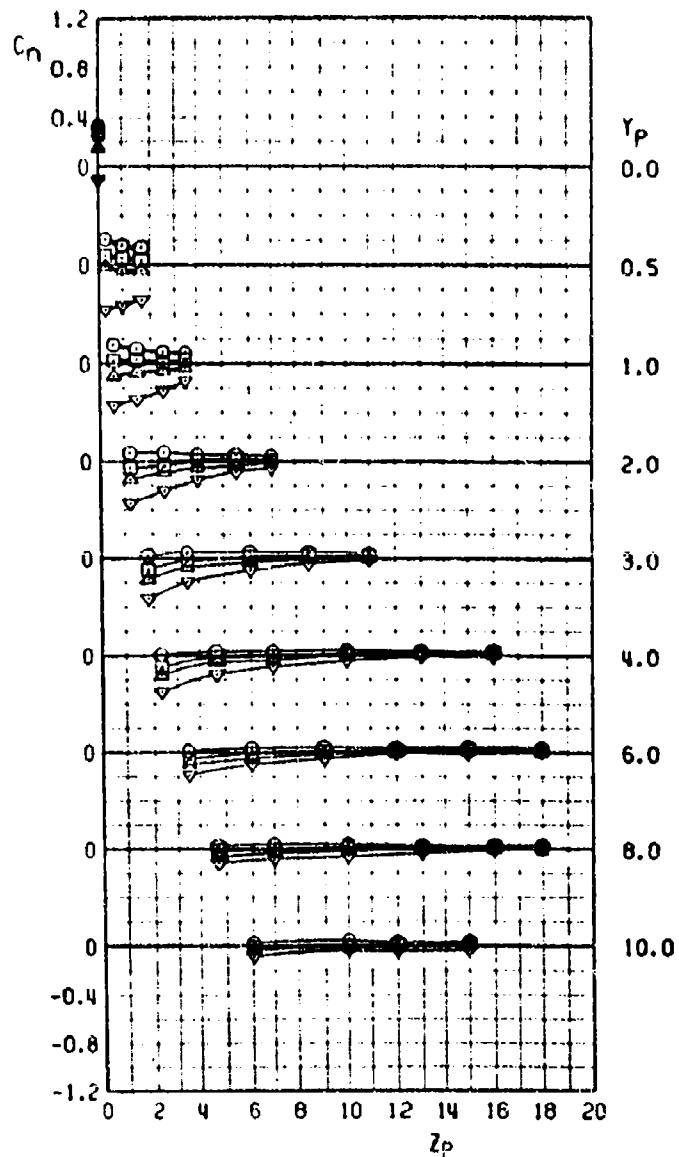
Figure 31. Concluded.



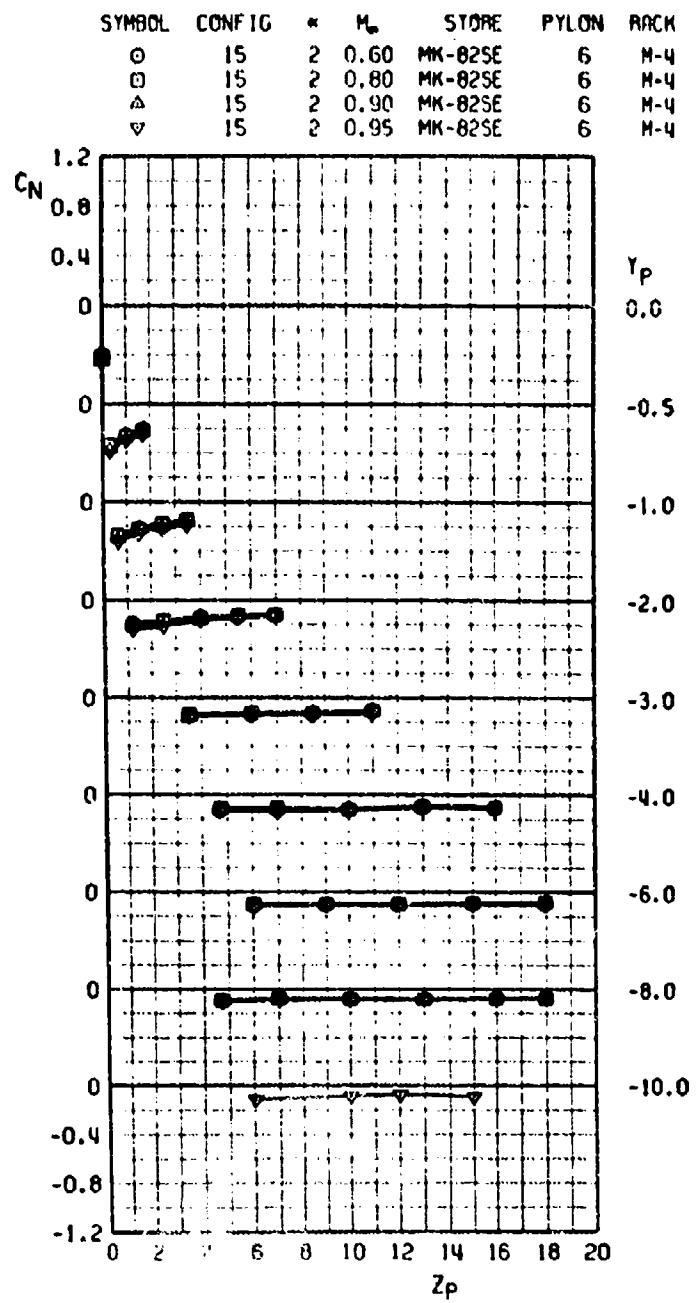
a. Side-force coefficient

Figure 32. MK-82SE coefficient variation with aircraft angle of attack, configuration 14.

SYMBOL	CONFIG	M_e	STORE	PYLON	RACK	
○	14	2	0.60	MK-82SE	6	M-6
□	14	4	0.60	MK-82SE	6	M-6
△	14	6	0.60	MK-82SE	6	M-6
▽	14	10	0.60	MK-82SE	6	M-6

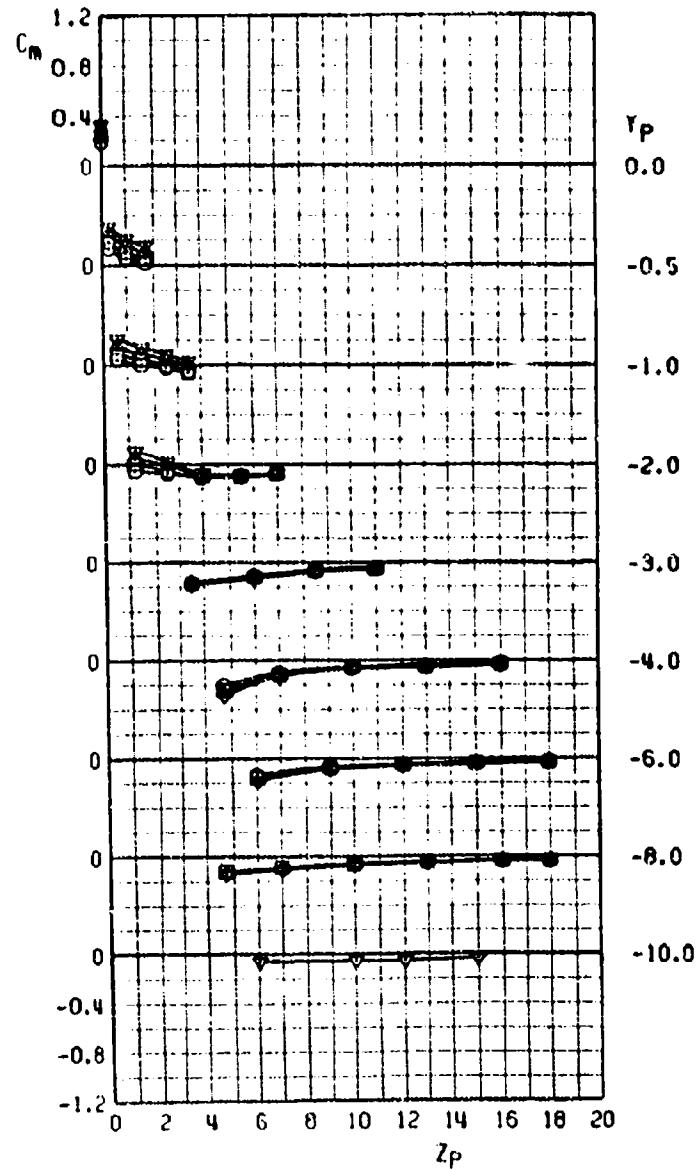


b. Yawing-moment coefficient
Figure 32. Concluded.

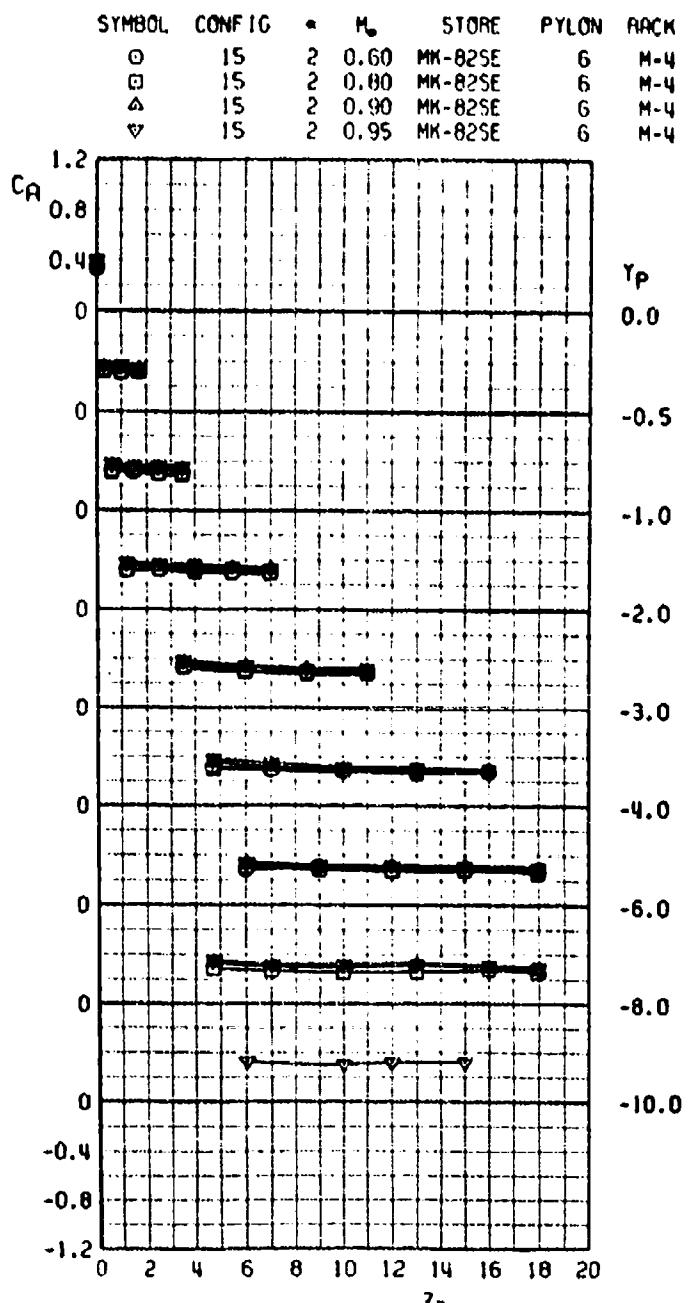


a. Normal-force coefficient
Figure 33. Aerodynamic characteristics of the MK-82SE, configuration 15.

SYMBOL	CONFIG	α	M_e	STORE	PYLON	RACK
○	15	2	0.60	MK-82SE	6	M-4
□	15	2	0.80	MK-82SE	6	M-4
△	15	2	0.90	MK-82SE	5	M-4
▽	15	2	0.95	MK-82SE	6	M-4

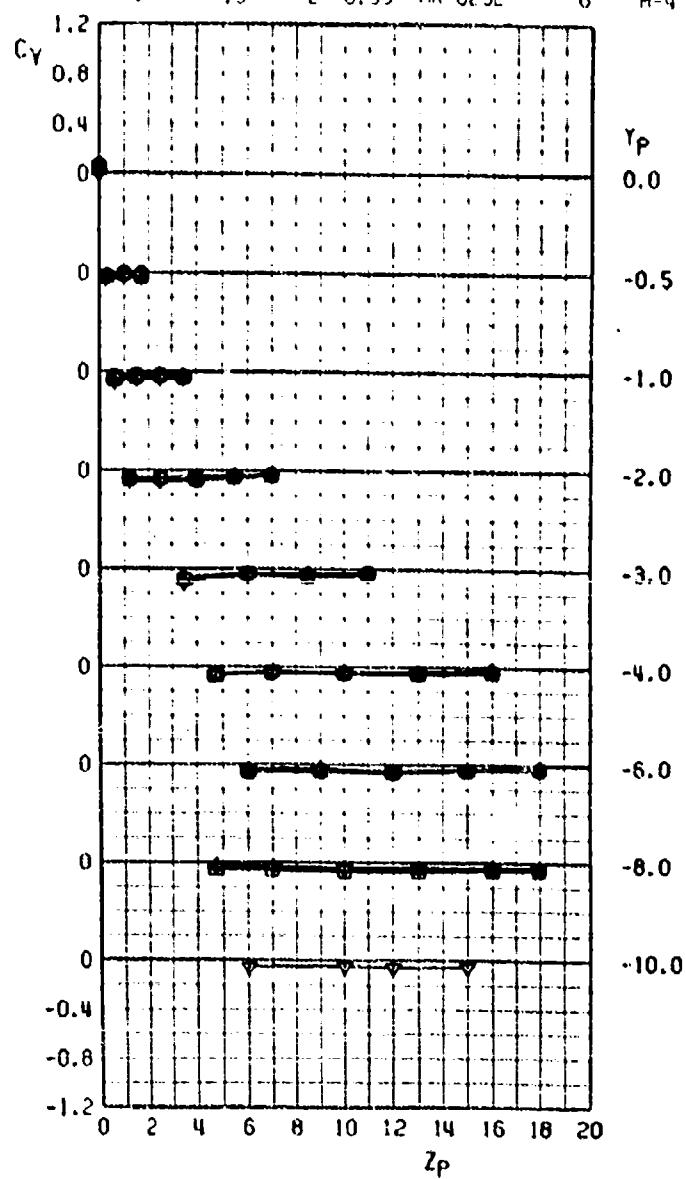


b. Pitching-moment coefficient
Figure 33. Continued.



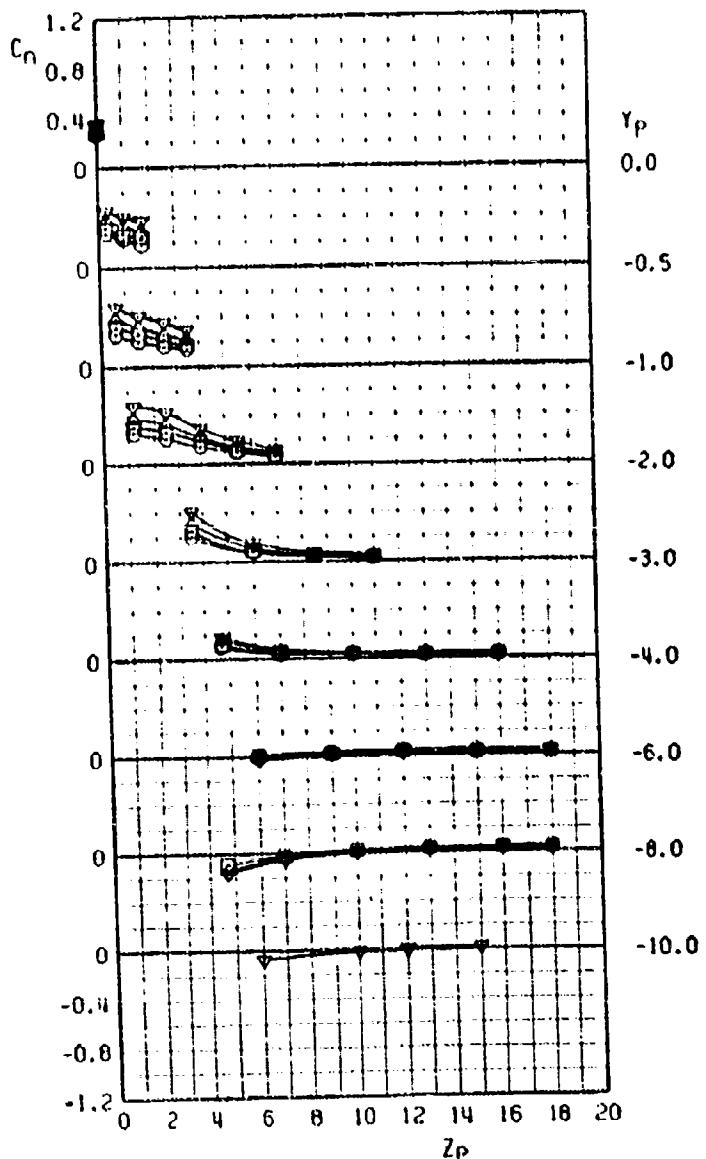
c. Axial-force coefficient
Figure 33. Continued.

SYMBOL	CONFIG	α	M_∞	STORE	PYLON	RACK
○	15	2	0.60	MK-02SE	6	M-4
◐	15	2	0.80	MK-02SE	6	M-4
△	15	2	0.90	MK-02SE	6	M-4
▽	15	2	0.95	MK-02SE	6	M-4



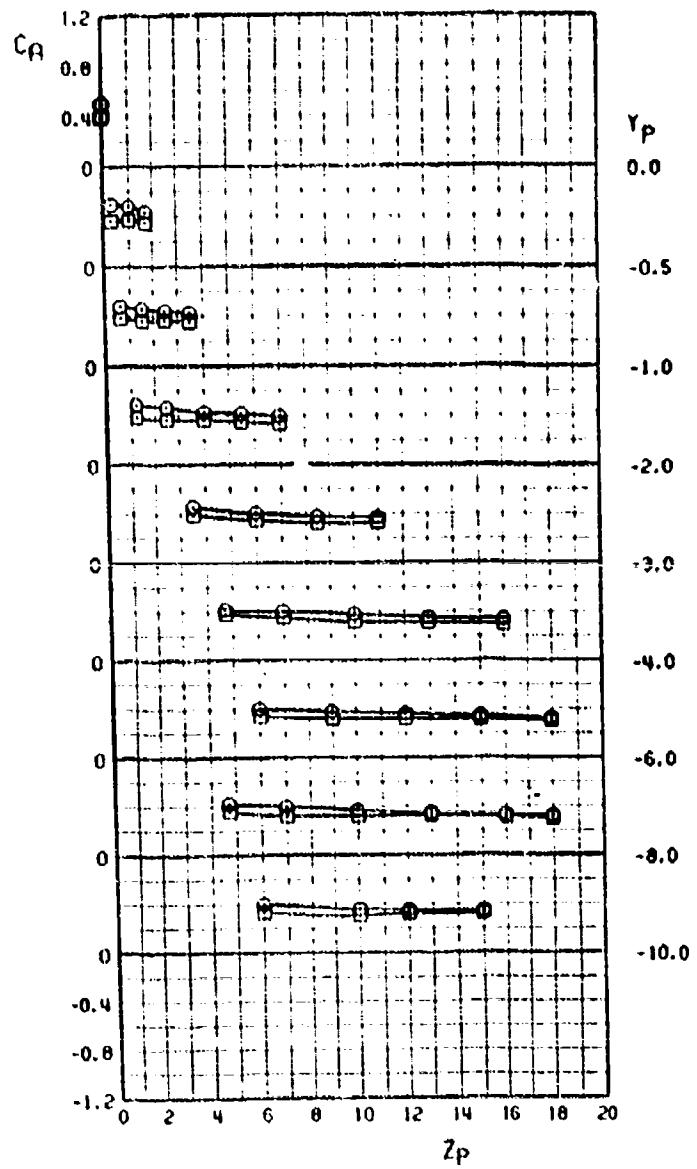
d. Side-force coefficient
Figure 33. Continued.

SYMBOL	CONFIG	M_e	STORE	PYLON	RACK	
○	15	2	0.60	MK-02SE	6	M-4
□	15	2	0.80	MK-02SE	6	M-4
△	15	2	0.90	MK-02SE	6	M-4
▽	15	2	0.95	MK-02SE	6	M-4



e. Yawing-moment coefficient
Figure 33. Concluded.

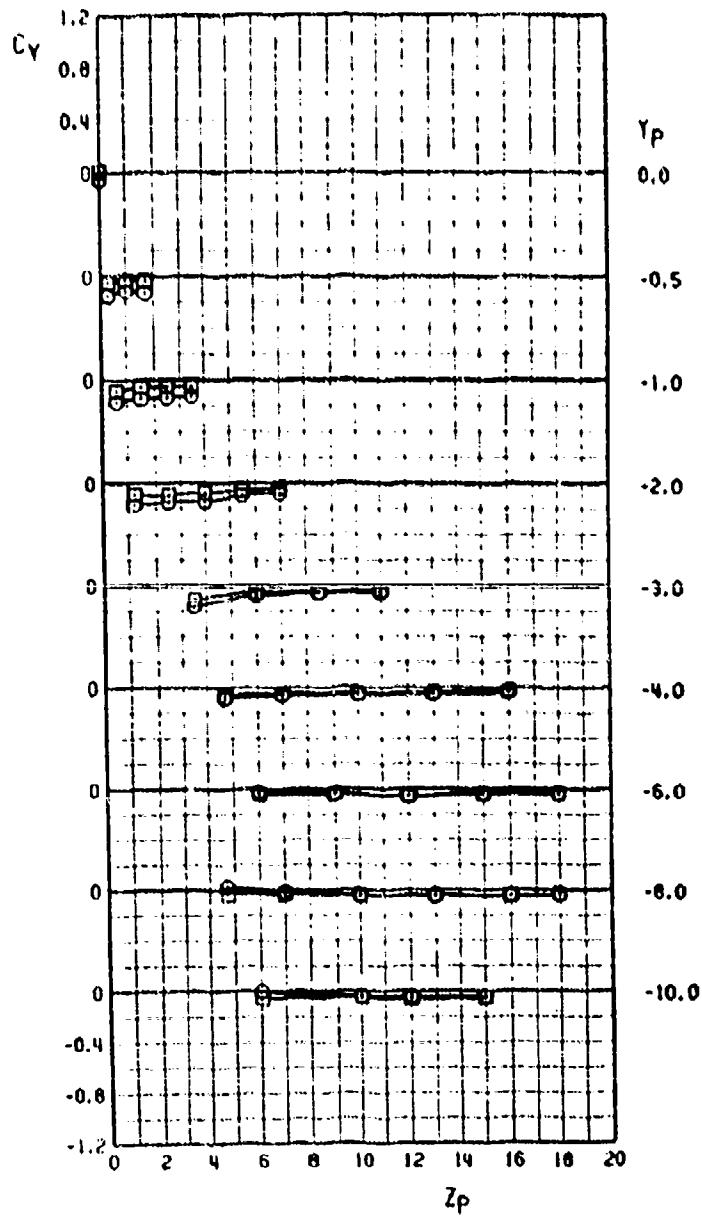
SYMBOL	CONFIG	α	M_∞	STONE	PYLON	RACK
○	15	0	0.95	MK-82SE	6	M-4
○	15	2	0.95	MK-82SE	6	M-4



a. Axial-force coefficient

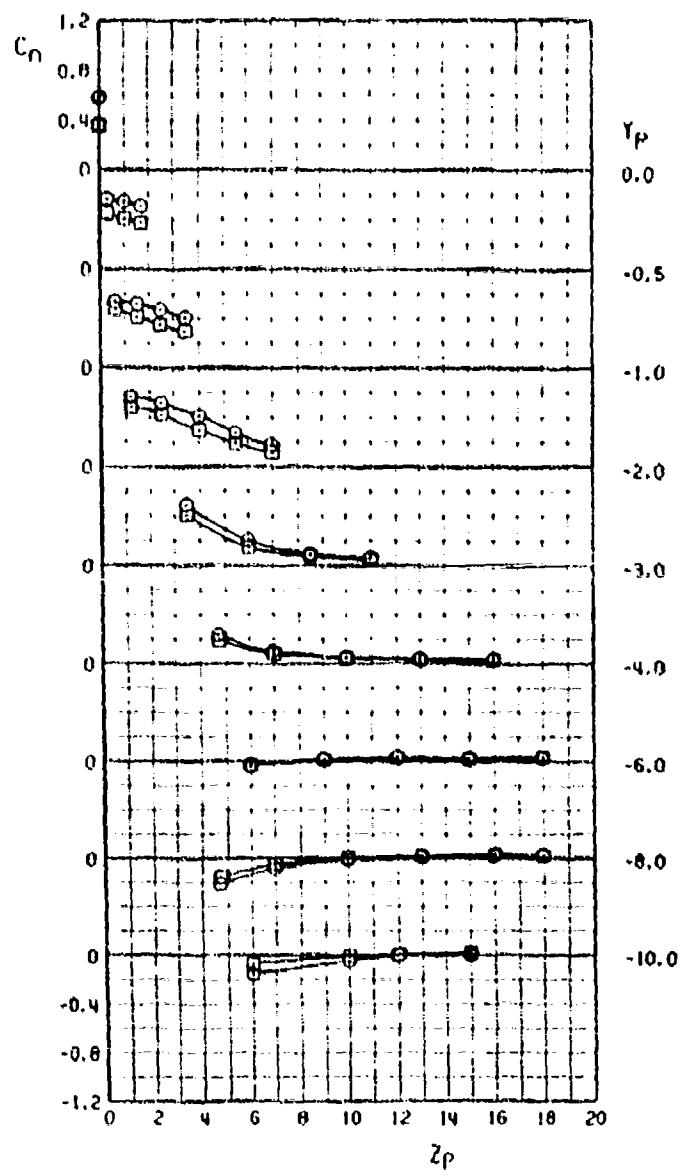
Figure 34. MK-82SE coefficient variation with aircraft angle of attack, configuration 15.

SYMBOL	CONFIG	α	M_a	STONE	PYLON	RACK
○	15	0	0.95	MK-82SE	6	M-4
□	15	2	0.95	MK-82SE	6	M-4



b. Side-force coefficient
Figure 34. Continued.

SYMBOL	CONFIG	α	M_∞	STORE	PYLON	RACK
○	15	0	0.95	MK-02SE	6	M-4
□	15	2	0.95	MK-02SE	6	M-4



c. Yawing-force coefficient
Figure 34. Concluded.

SYMBOL	CONFIG	R_e	STORE	PYLON
○	16	2	0.60	MK-82SE
□	16	2	0.80	MK-82SE
△	16	2	0.90	MK-82SE
▽	16	2	0.95	MK-82SE

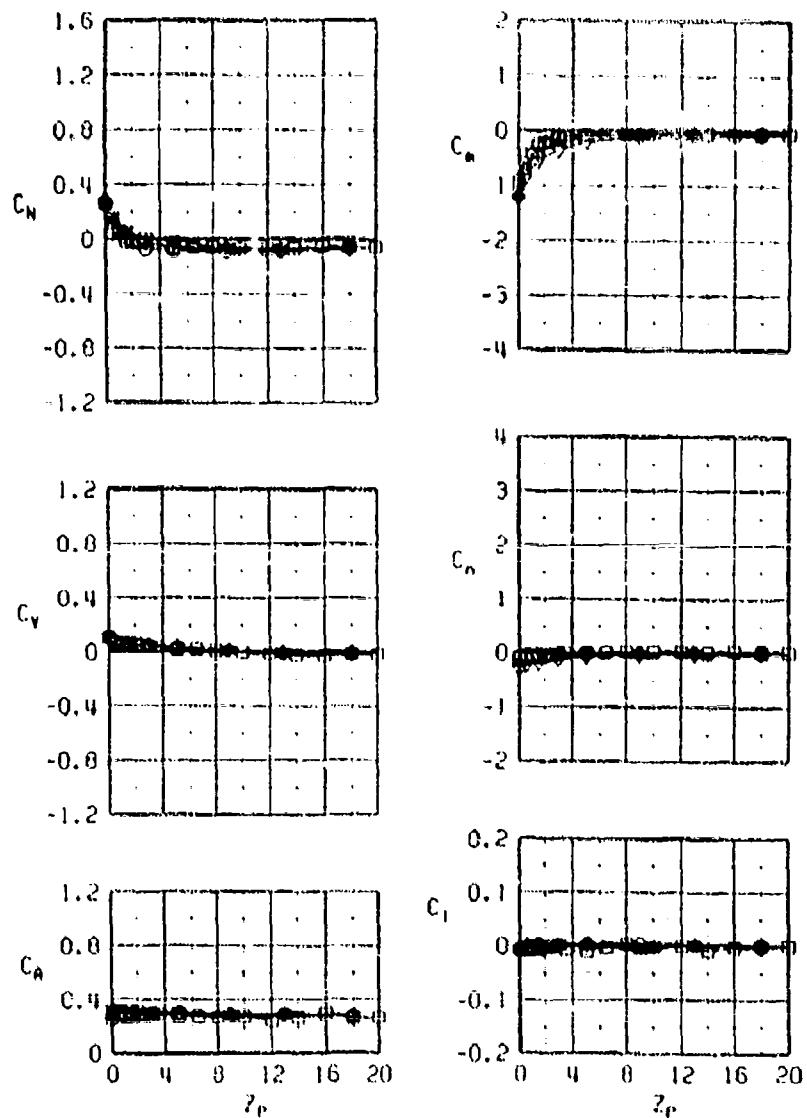


Figure 35. Aerodynamic characteristics of the MK-82SE, configuration 16.

SYMBOL	CONFIG	α	M_∞	STORE	PYLON
○	16	2	0.60	MK-82SE	?
□	16	4	0.60	MK-82SE	?
△	16	6	0.60	MK-82SE	?
▽	16	10	0.60	MK-82SE	?

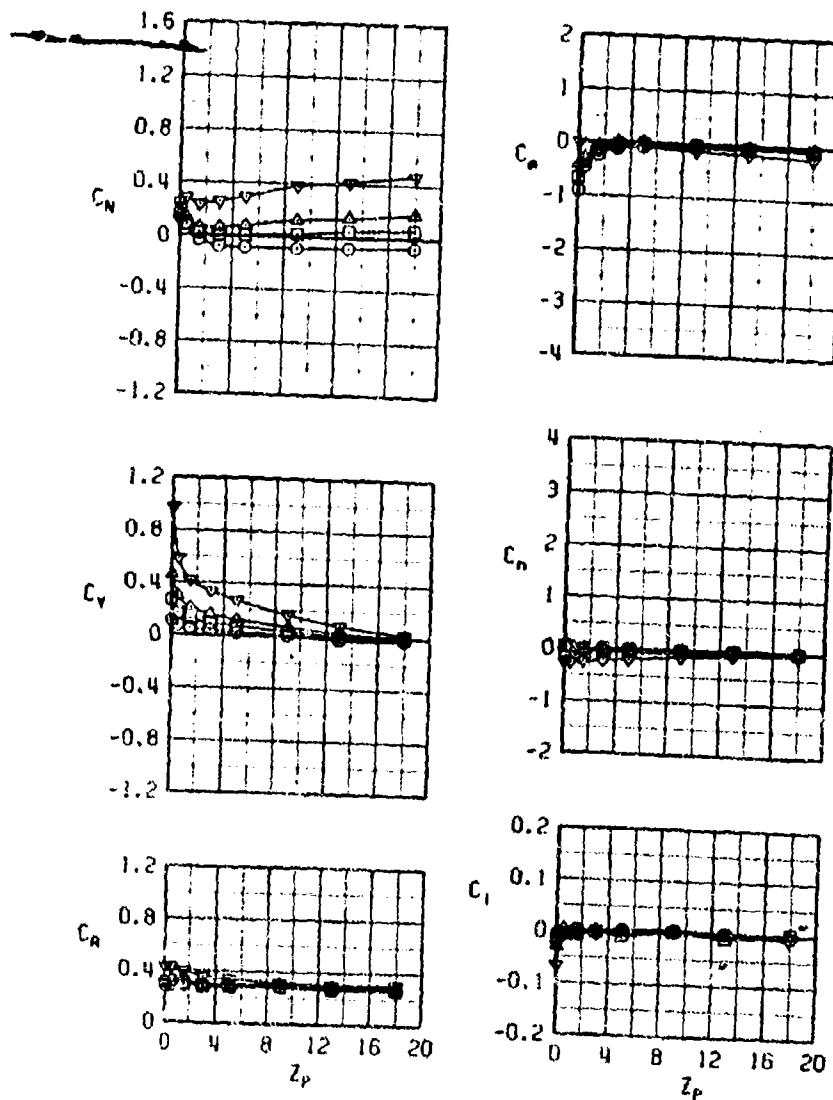


Figure 36. MK-82SE coefficient variation with aircraft angle of attack, configuration 16.

SYMBOL	CONFIG	α	M_∞	STORE	PYLON
○	17	2	0.60	MK-82SE	6
□	17	2	0.80	MK-82SE	6
△	17	2	0.90	MK-82SE	6
▽	17	2	0.95	MK-82SE	6

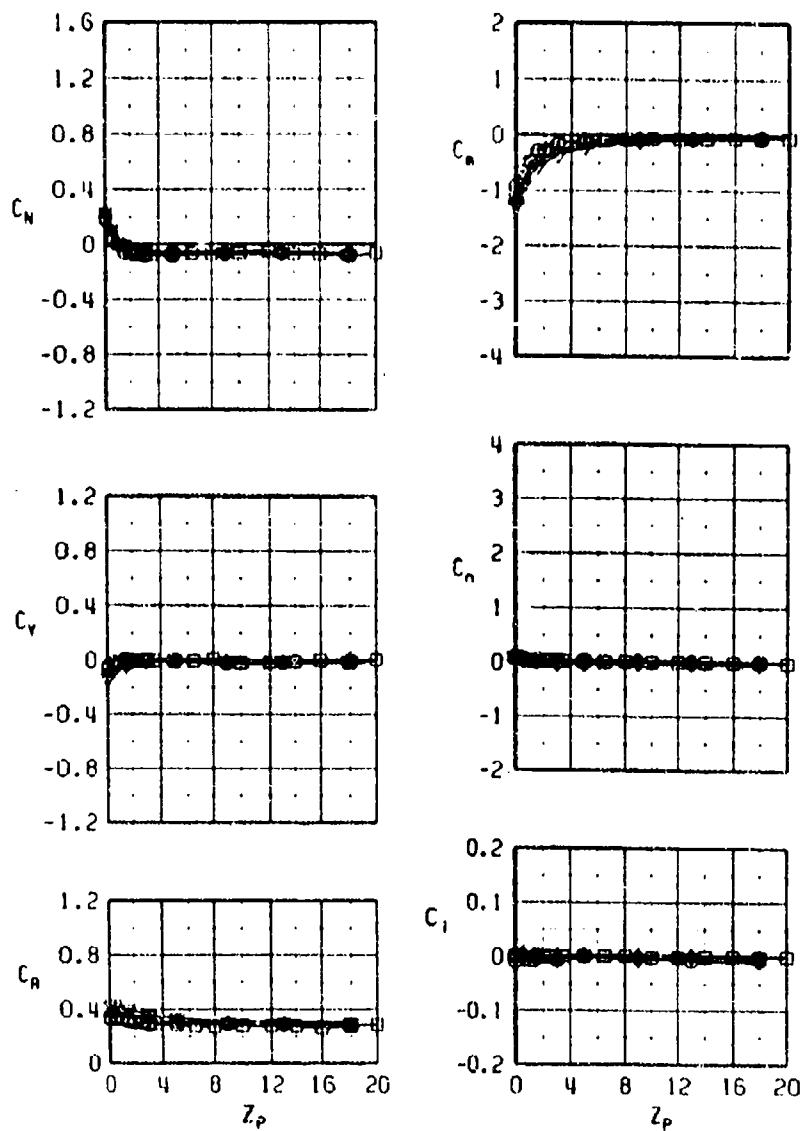


Figure 37. Aerodynamic characteristics of the MK-82SE, configuration 17.

SYMBOL	CONFIG	M_∞	STOKE	PYLON
○	17	2	0.60	MK-82SE
□	17	4	0.60	MK-82SE
△	17	6	0.60	MK-82SE
▽	17	10	0.60	MK-82SE

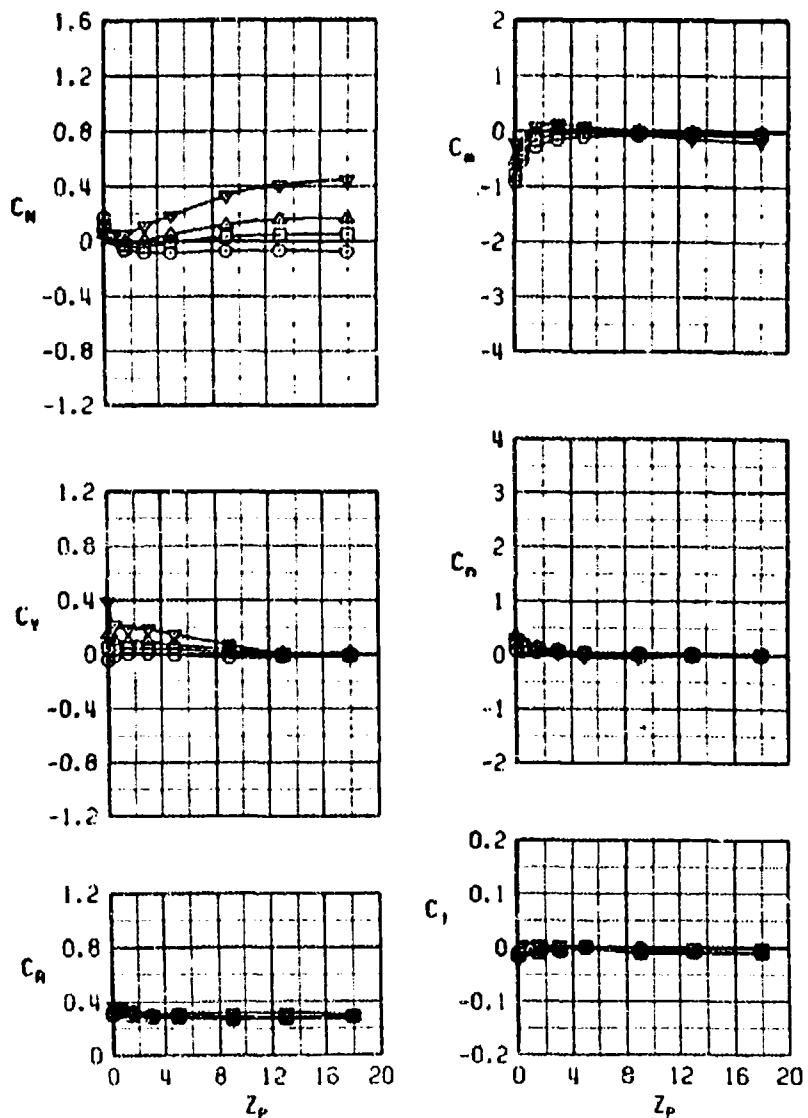


Figure 38. MK-82SE coefficient variation with aircraft angle of attack, configuration 17.

SYMBOL	CONFIG	α	M_∞	STORE	PILEON	RACK	δ_{LE}
○	10	10	0.60	MM-B2SE	7	7-1	0
□	10	10	0.60	MM-B2SE	7	7-1	15

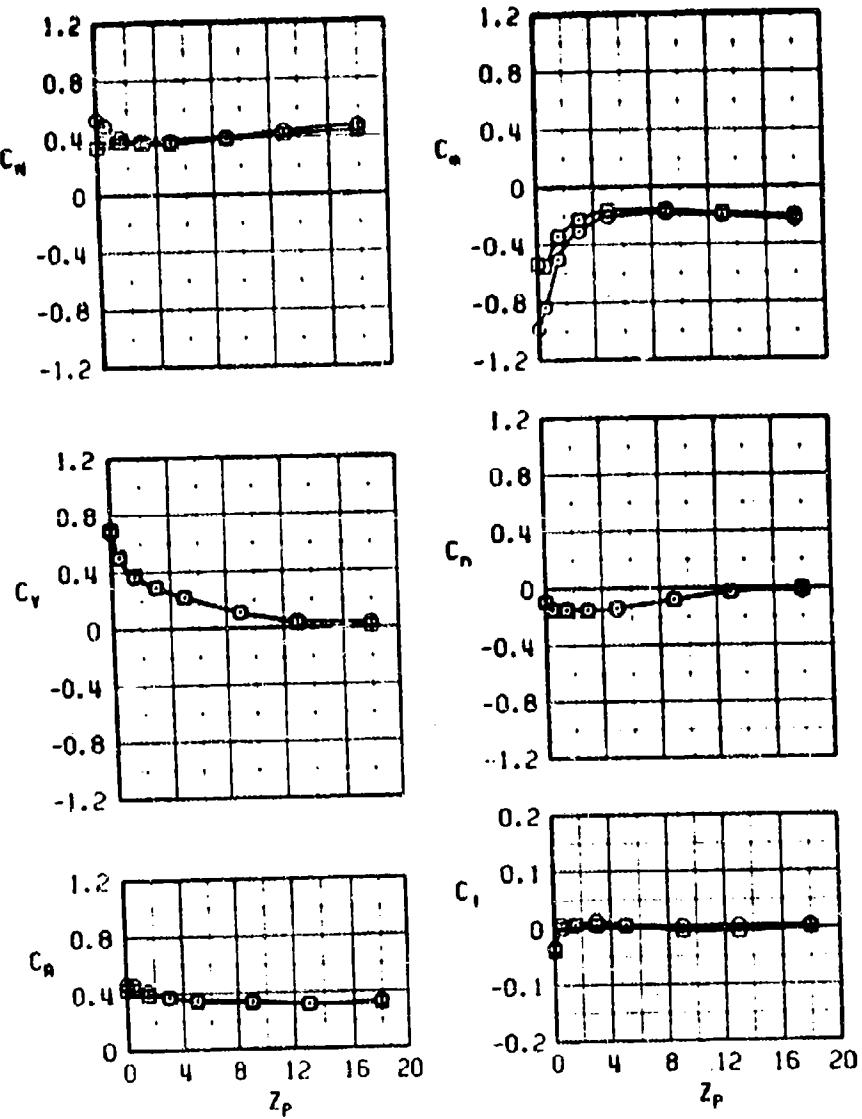
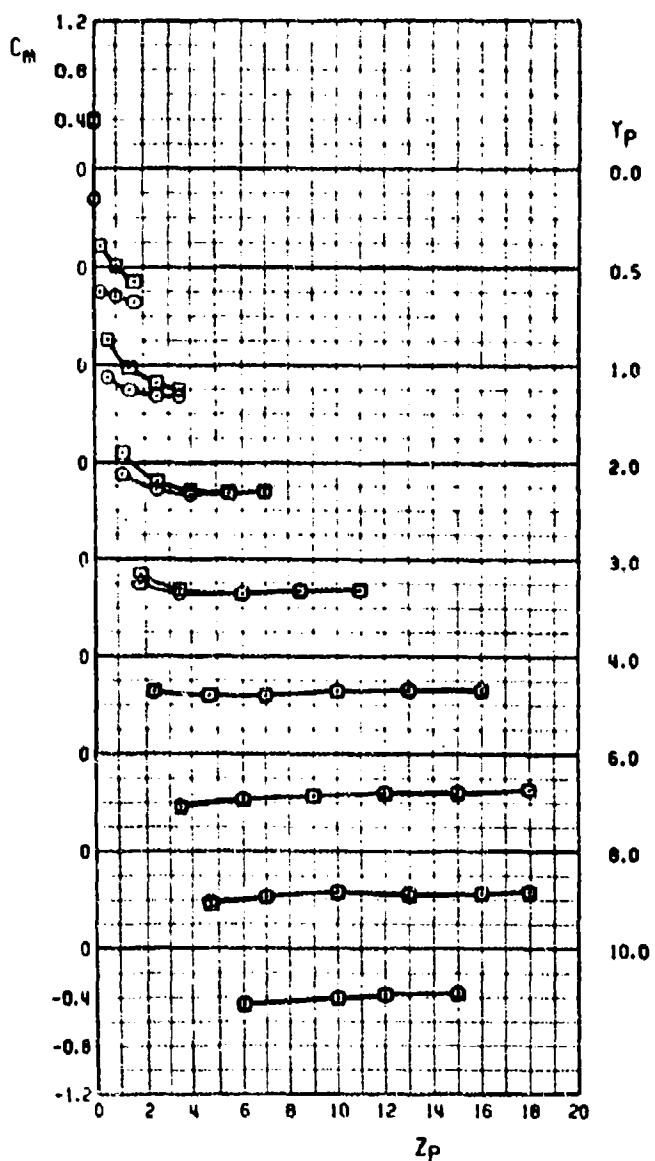


Figure 39. Coefficient w/ wing leading-edge-flap deflection, configuration 10.

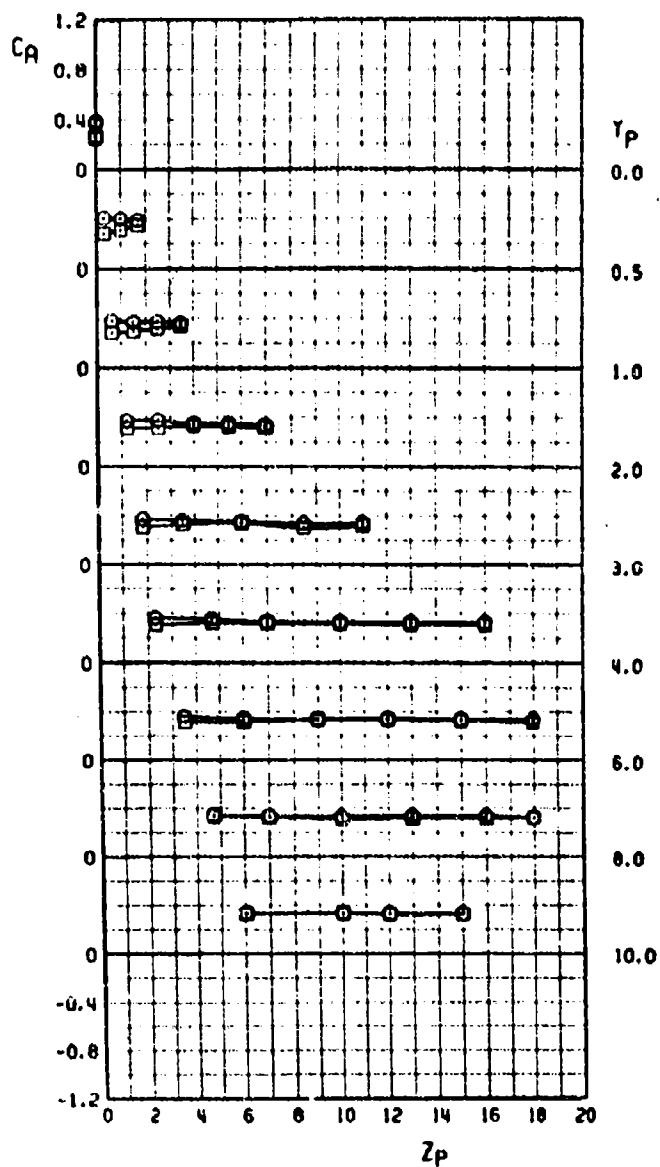
SYMBOL	CONFIG	α	M_∞	STORE	PYLON	RACK	q_e
○	11	10	0.60	MK-82SE	7	T-3	0
□	11	10	0.60	MK-82SE	7	T-3	15



a. Pitching-moment coefficient

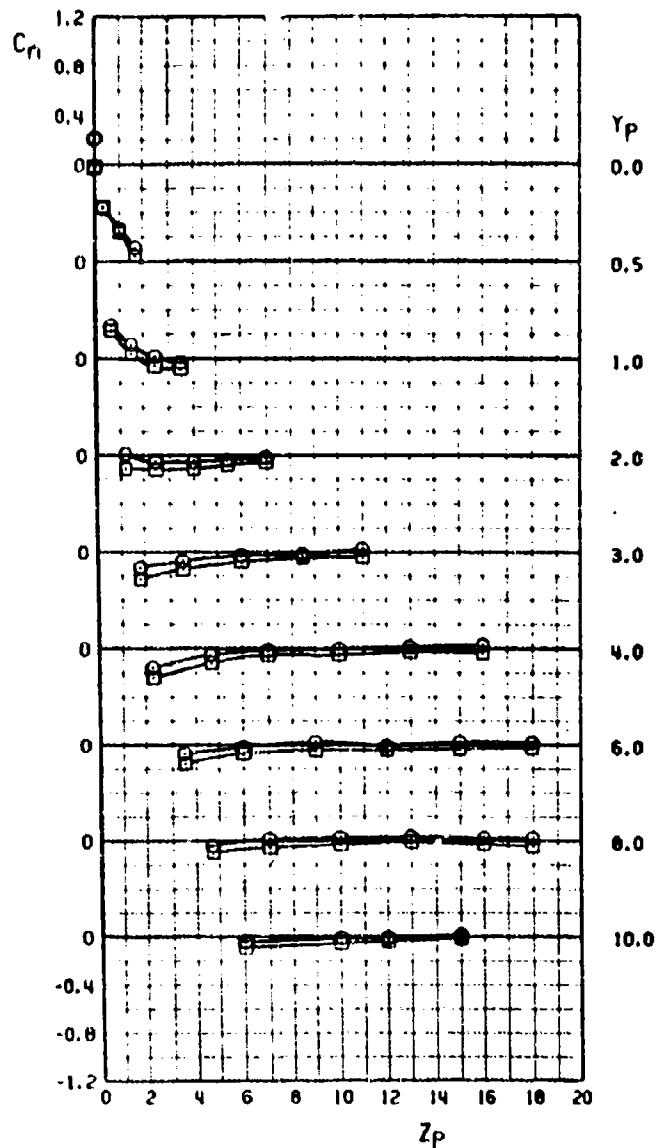
Figure 40. Coefficient variation with wing leading-edge-flap deflection, configuration 11.

SYMBOL	CONFIG	α	M_∞	STORE	PYLON	RACK	t_c
○	II	10	0.60	MK-82SE	7	T-3	0
□	II	10	0.60	MK-82SE	7	T-3	15



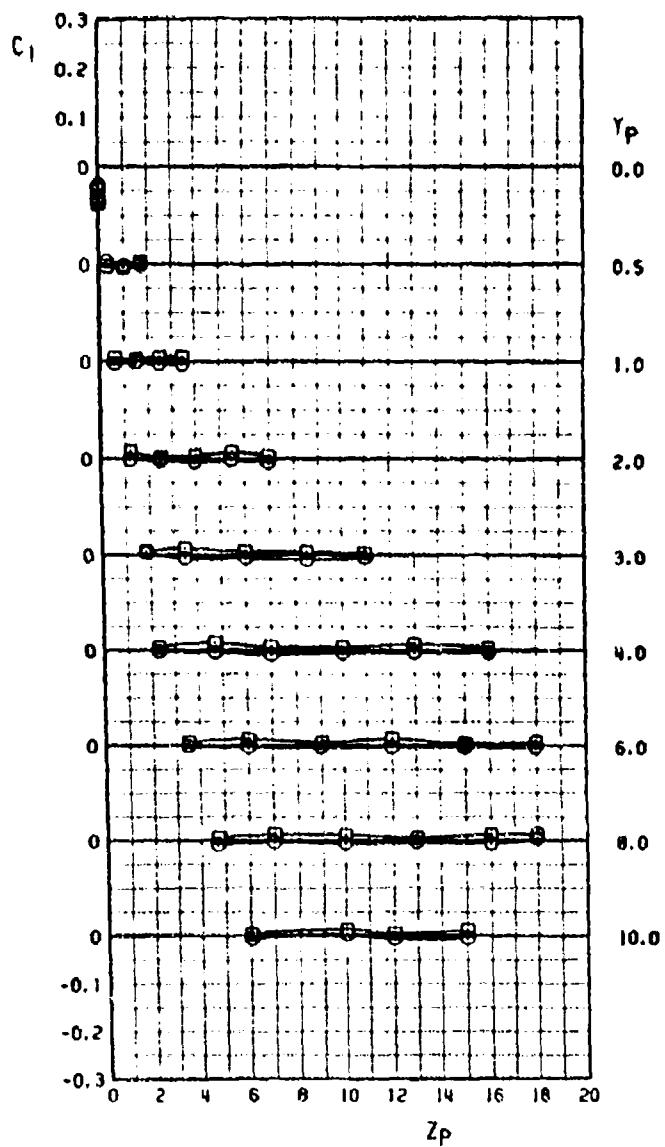
b. Axial-force coefficient
Figure 40. Continued.

SYMBOL	CONFIG	*	M ₀	STORE	PYLON	RACK	α_e
○	II	10	0.60	MM-82SE	7	1-3	0
□	II	10	0.60	MM-82SE	7	1-3	15



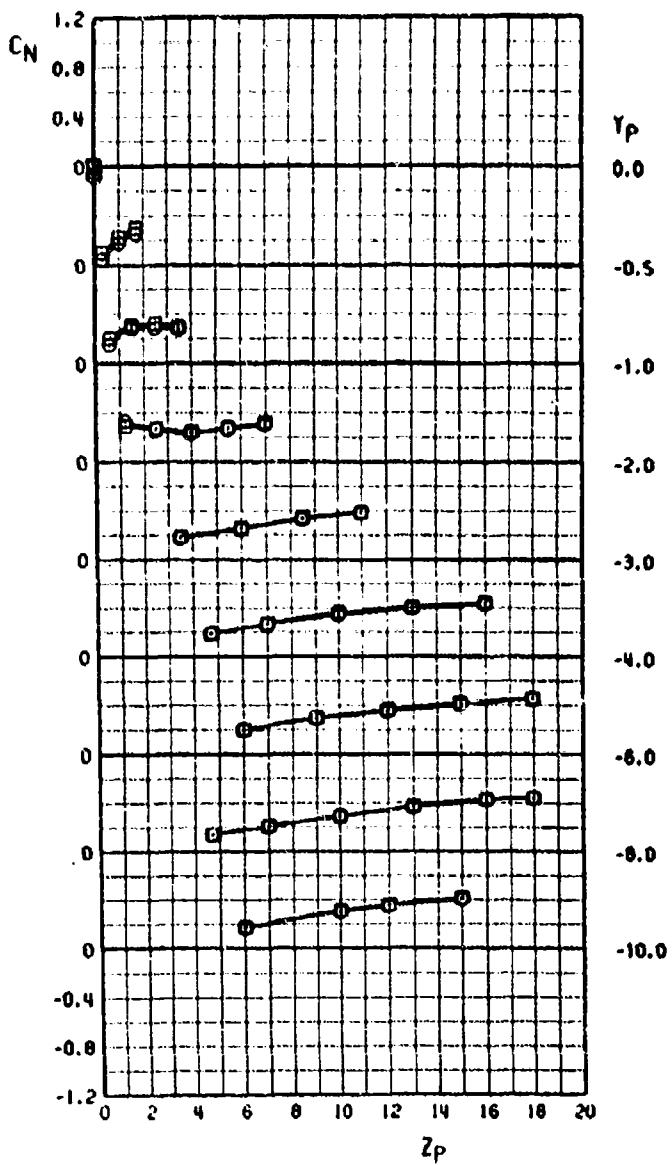
c. Yawing-moment coefficient
Figure 40. Continued.

SYMBOL	CONFIG	α	M_0	STORE	PYLON	RACK	δ_{LE}
○	II	10	0.60	MM-82SE	7	T-3	0
□	II	10	0.60	MM-82SE	7	T-3	15



d. Rolling-moment coefficient
Figure 40. Concluded.

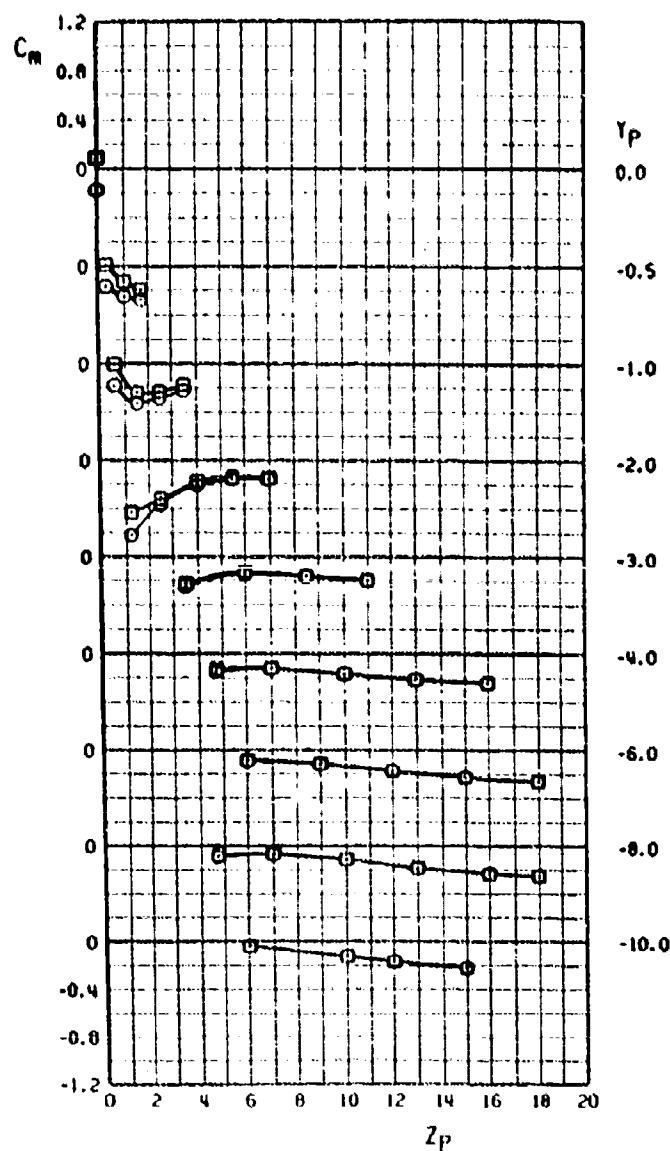
SYMBOL	CONFIG	α	M_∞	STORE	PYLON	RACK	δ_{LE}
O	12	10	0.60	MK-82SE	7	1-2	0
D	12	10	0.60	MK-82SE	7	1-2	15



a. Normal-force coefficient

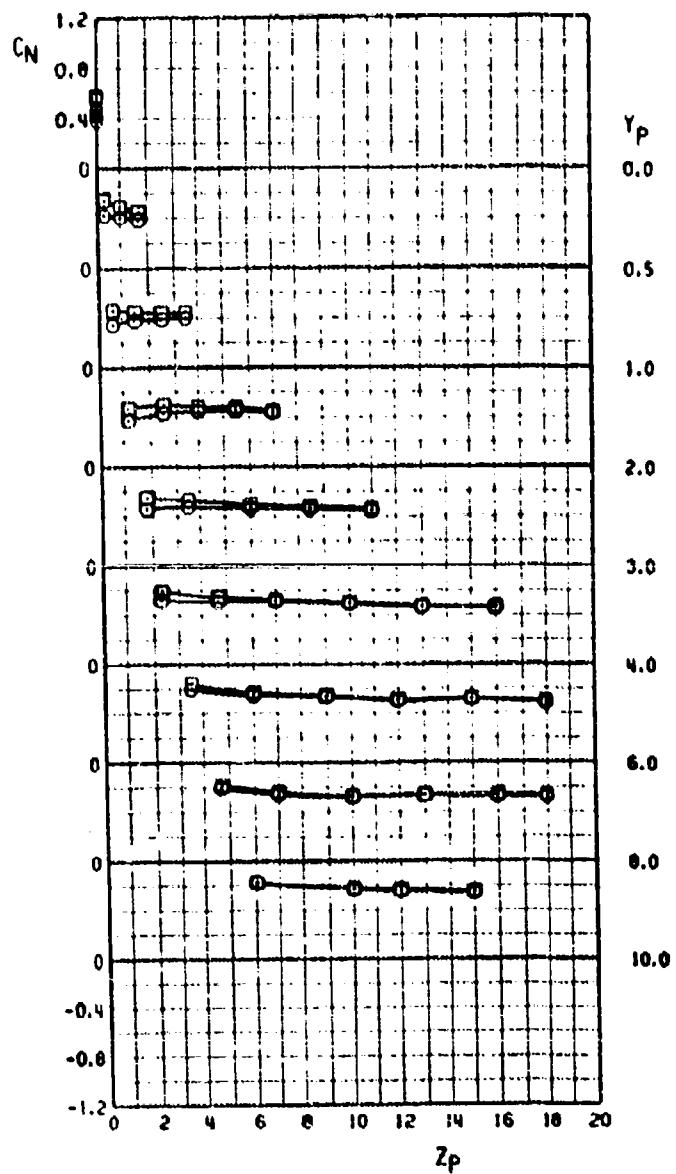
Figure 41. Coefficient variation with wing leading-edge-flap deflection, configuration 12.

SYMBOL	CONFIG	α	M_∞	STORE	PYLON	RACK	SLE
○	12	10	0.60	MK-82SE	7	T-2	0
□	12	10	0.60	MK-82SE	7	T-2	15



b. Pitching-moment coefficient
Figure 41. Concluded.

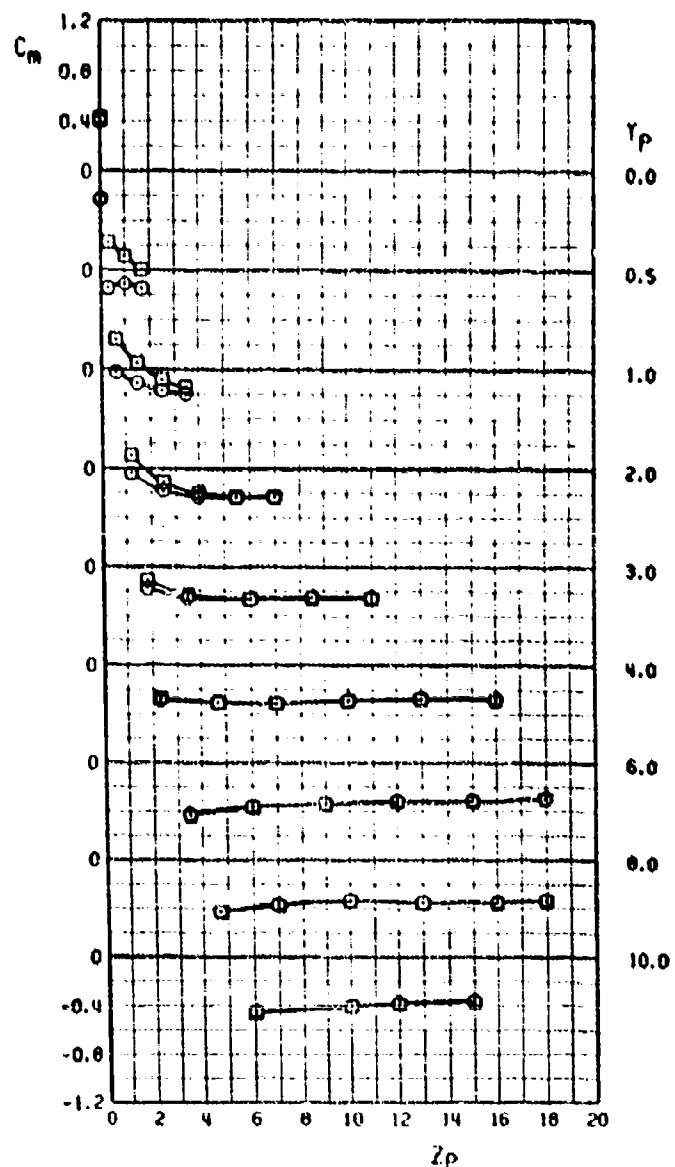
SYMBOL	CONFIG	α	M_∞	STORE	PYLON	RACK	δ_{LE}
○	13	10	0.60	MK-82SE	?	1-3	0
□	13	10	0.60	MK-82SE	?	1-3	15



a. Normal-force coefficient

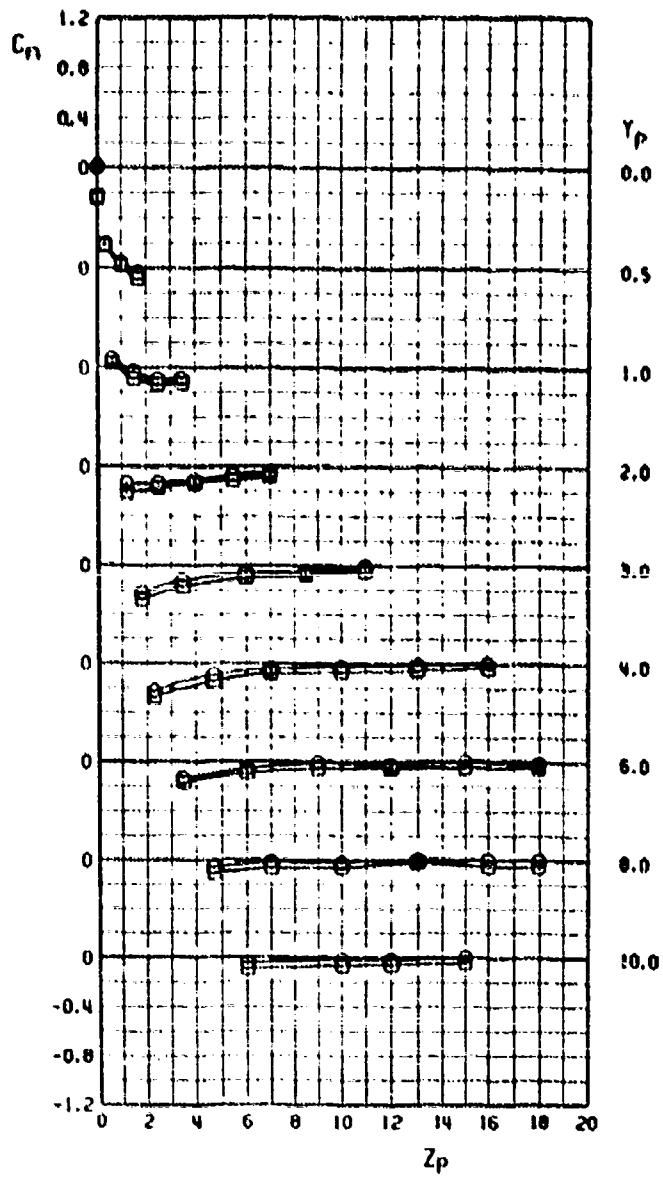
Figure 42. Coefficient variation with wing leading-edge-flap deflection, configuration 13.

SYMBOL.	CONFIG	α	M_∞	STONE	PYLON	RACK	α_s
○	13	10	0.60	MM-82SE	7	T-3	0
□	13	10	0.60	MM-82SE	7	T-3	15



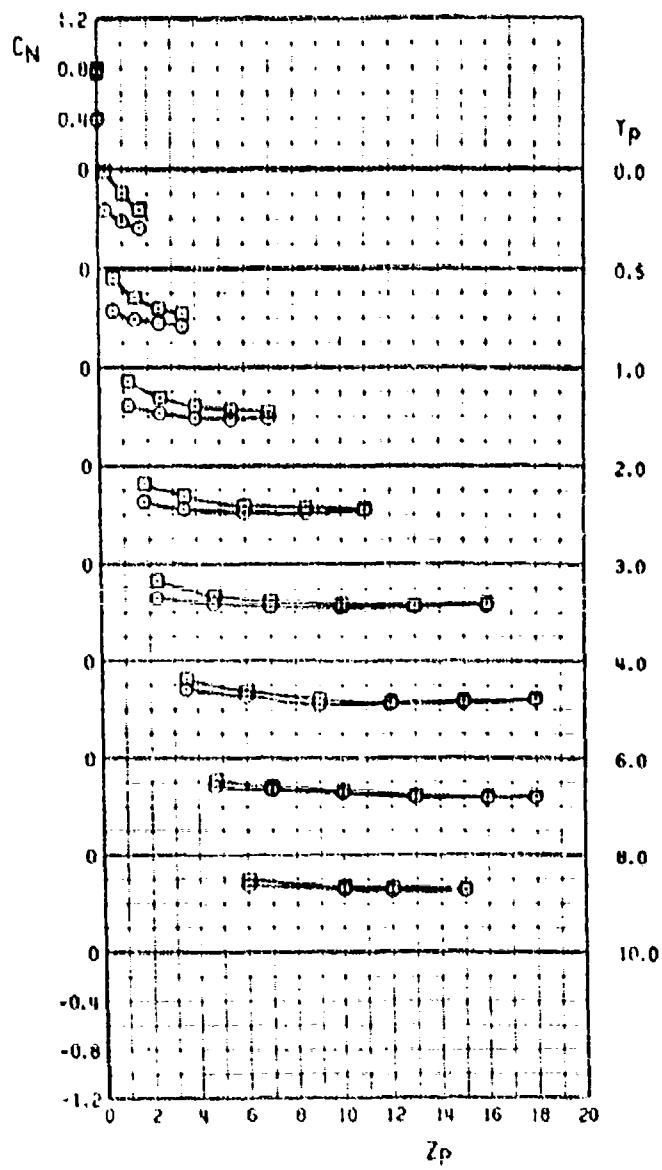
b. Pitching-moment coefficient
Figure 42. Continued.

SYMBOL	CONFIG	α	M_c	STORE	PYLON	MACK	q_e
○	13	10	0.60	MM-82SE	7	1-3	0
□	13	10	0.60	MM-82SE	7	1-3	15



c. Yawing-moment coefficient
Figure 42. Concluded.

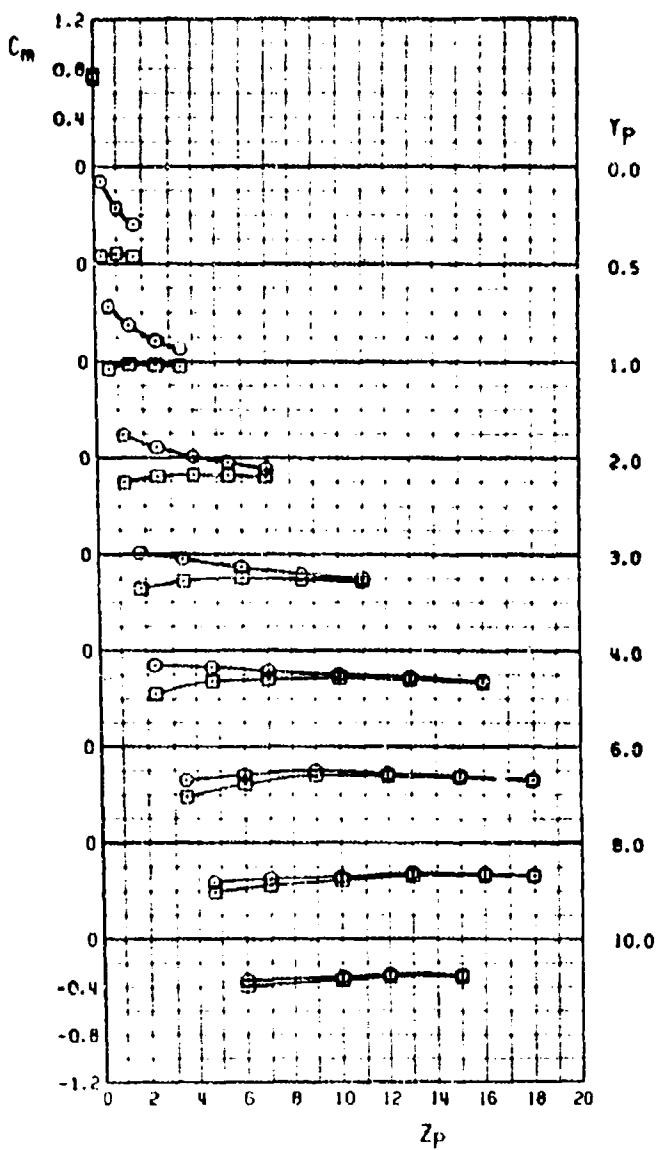
SYMBOL	CONFIG	α	M_∞	STONE	PTYLON	RACK	δ_{LE}
○	14	10	0.60	MK-02SE	6	M-6	0
□	14	10	0.60	MK-02SC	6	M-6	15



a. Normal-force coefficient

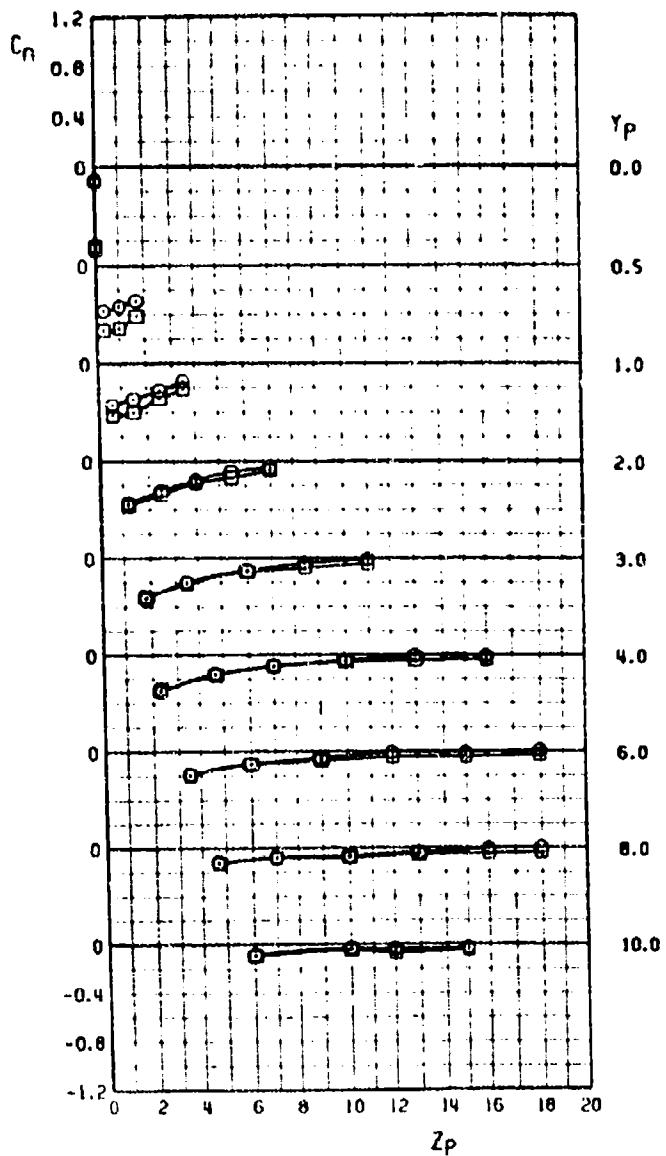
Figure 43. Coefficient variation with wing leading-edge-flap deflection, configuration 14.

	SYMBOL	CONFIG	α	M_∞	STORE	PYLON	RACK	β_c
1.	○	14	10	0.60	MK-82SE	6	M-6	0
2.	□	14	10	0.60	MK-82SE	6	M-6	15



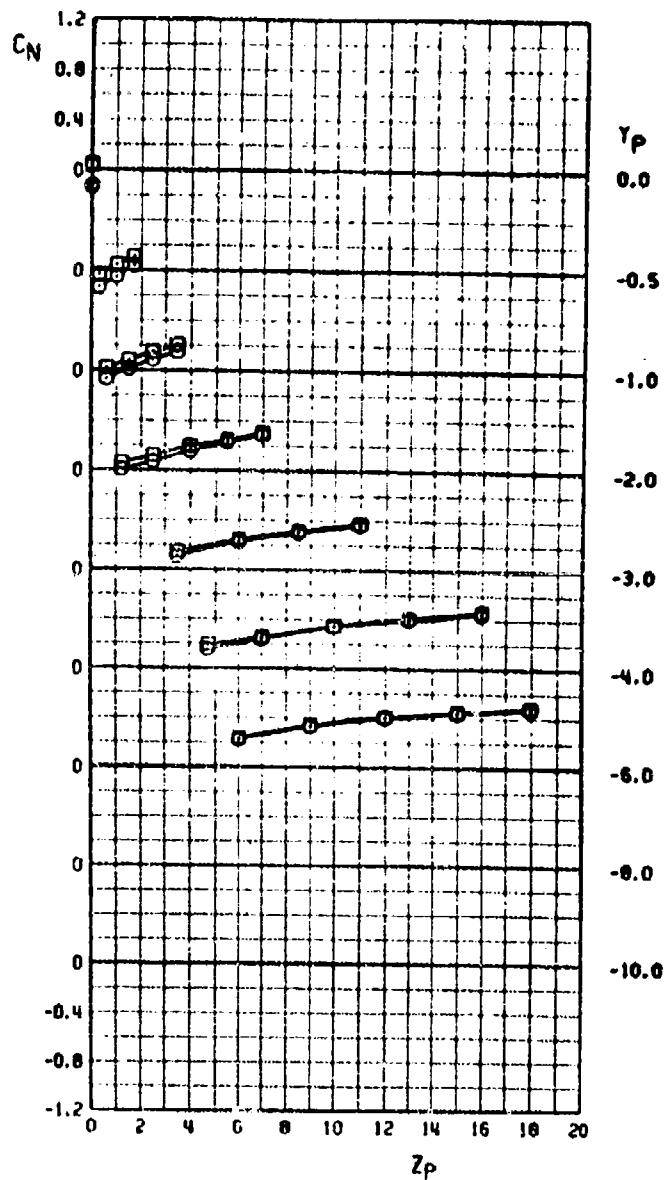
b. Pitching-moment coefficient
Figure 43. Continued.

SYMBOL	CONFIG	α	M_a	STORE	PYLON	RACK	Δc
○	14	10	0.60	MM-82SE	6	M-6	0
□	14	10	0.60	MM-82SE	6	M-6	15



c. Yawing-moment coefficient
Figure 43. Concluded.

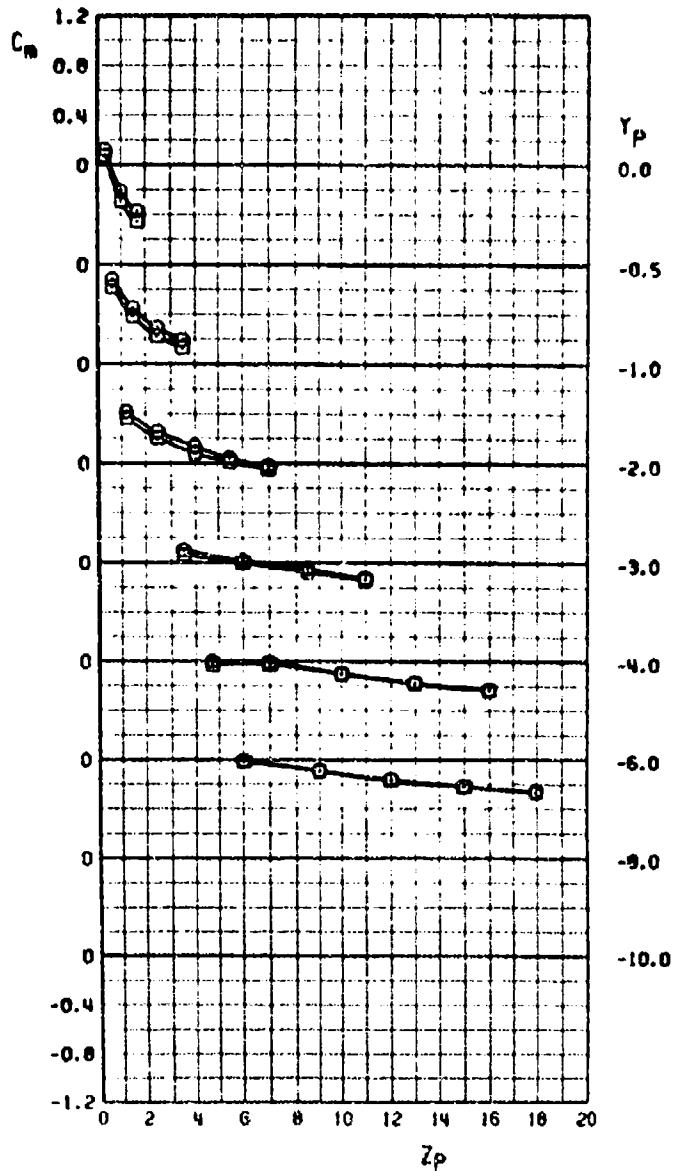
SYMBOL	CONFIG	α	M_∞	STORE	PYLON	RACK	q_e
○	15	10	0.60	MM-82SE	6	M-4	0
□	15	10	0.60	MM-82SE	6	M-4	15



a. Normal-force coefficient

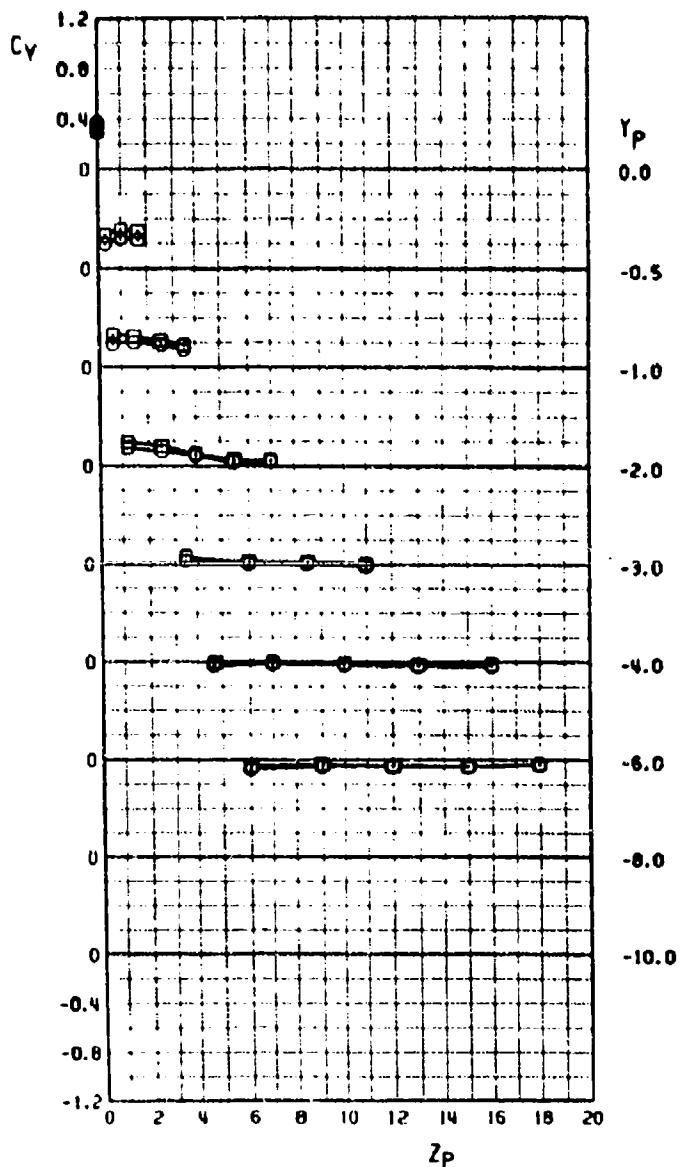
Figure 44. Coefficient variation with wing leading-edge-flap deflection, configuration 15.

SYMBOL	CONFIG	α	M_∞	STORE	PYLON	RACK	α_x
○	15	10	0.60	MK-82SE	6	M-4	0
□	15	10	0.60	MK-82SE	6	M-4	15



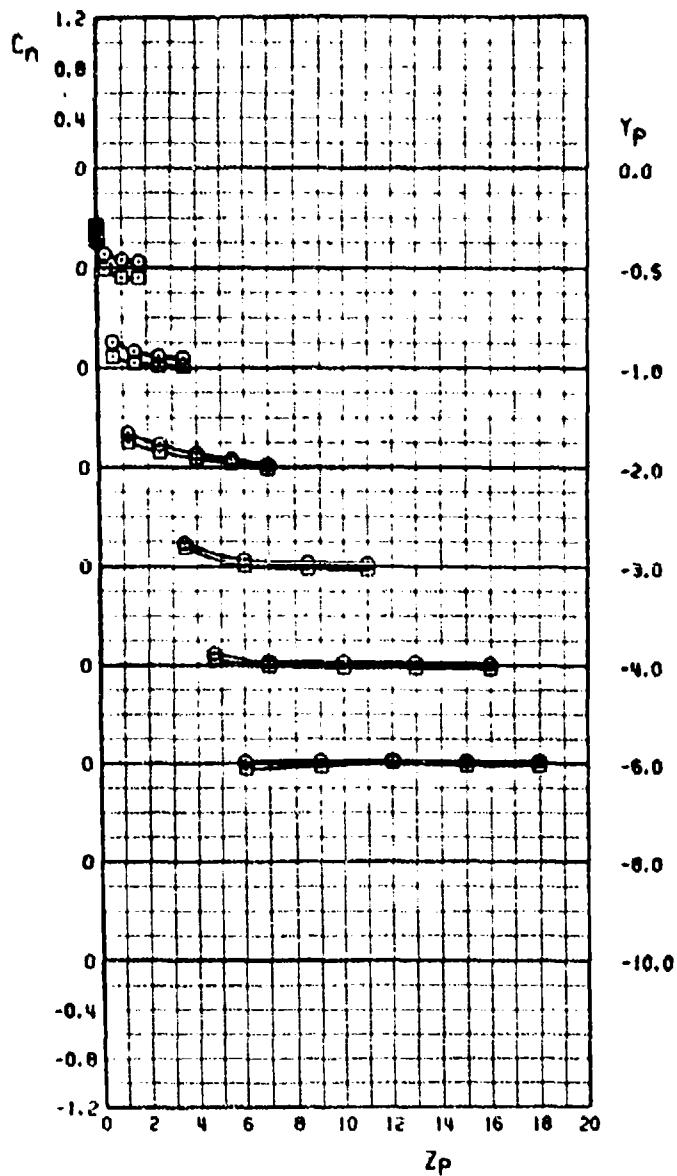
b. Pitching-moment coefficient
Figure 44. Continued.

SYMBOL	CONFIG	α	M_∞	STORE	PYLON	RACK	q_{re}
○	15	10	0.60	MM-82SE	6	M-4	0
□	15	10	0.60	MM-82SE	6	M-4	15



c. Side-force coefficient
Figure 44. Continued.

SYMBOL	CONFIG	α	M ₀	STORE	PYLON	PACK	α_c
○	15	10	0.60	MN-82SE	6	M-4	0
□	15	10	0.60	MK-82SE	6	M-4	15



d. Yawing-moment coefficient
Figure 44. Concluded.

SYMBOL	CONFIG	α	M_∞	STORE	PYLON	RACK	q_e
○	16	10	0.60	MM-82SE	7	NA	0
□	16	10	0.60	MM-82SE	7	NA	15

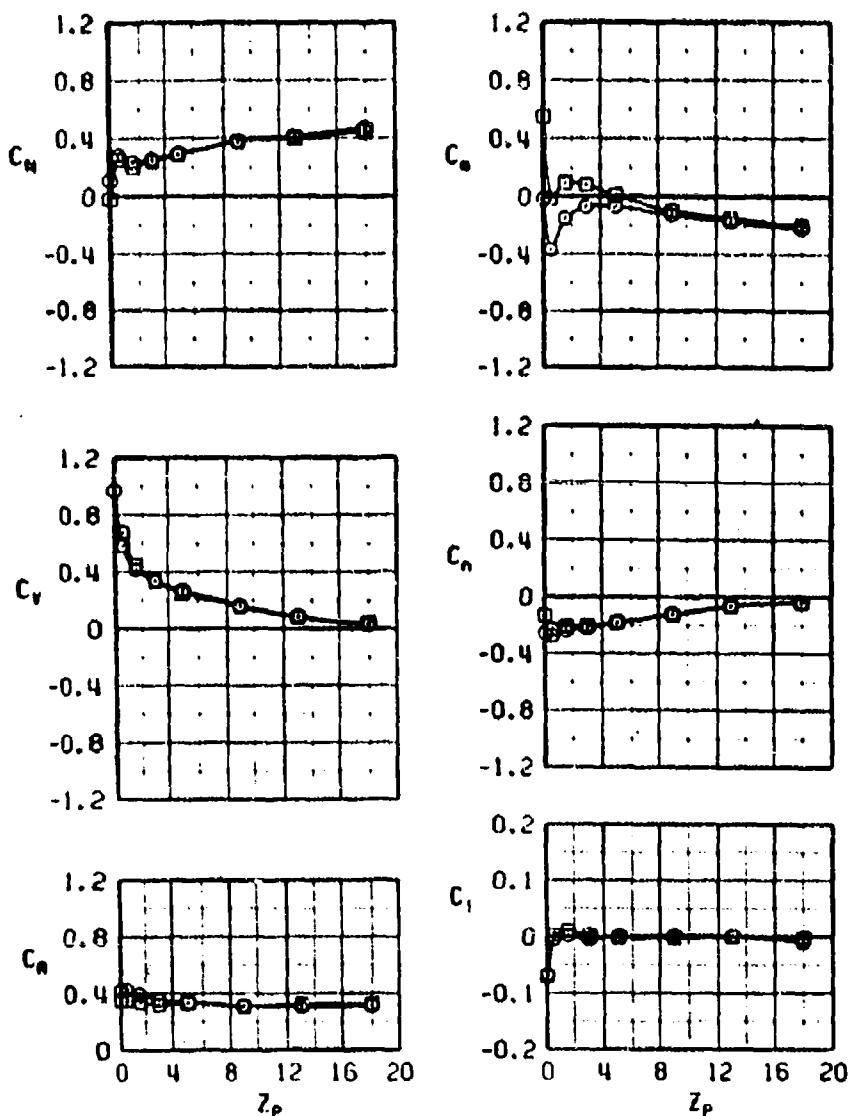


Figure 45. Coefficient variation with wing leading-edge-flap deflection, configuration 16.

SYMBOL	CONFIG	α	M_∞	STORE	PYLON	RACK	δ_{LE}
○	17	10	0.60	MK-82SE	6	NA	0
□	17	10	0.60	MK-82SE	6	NA	15

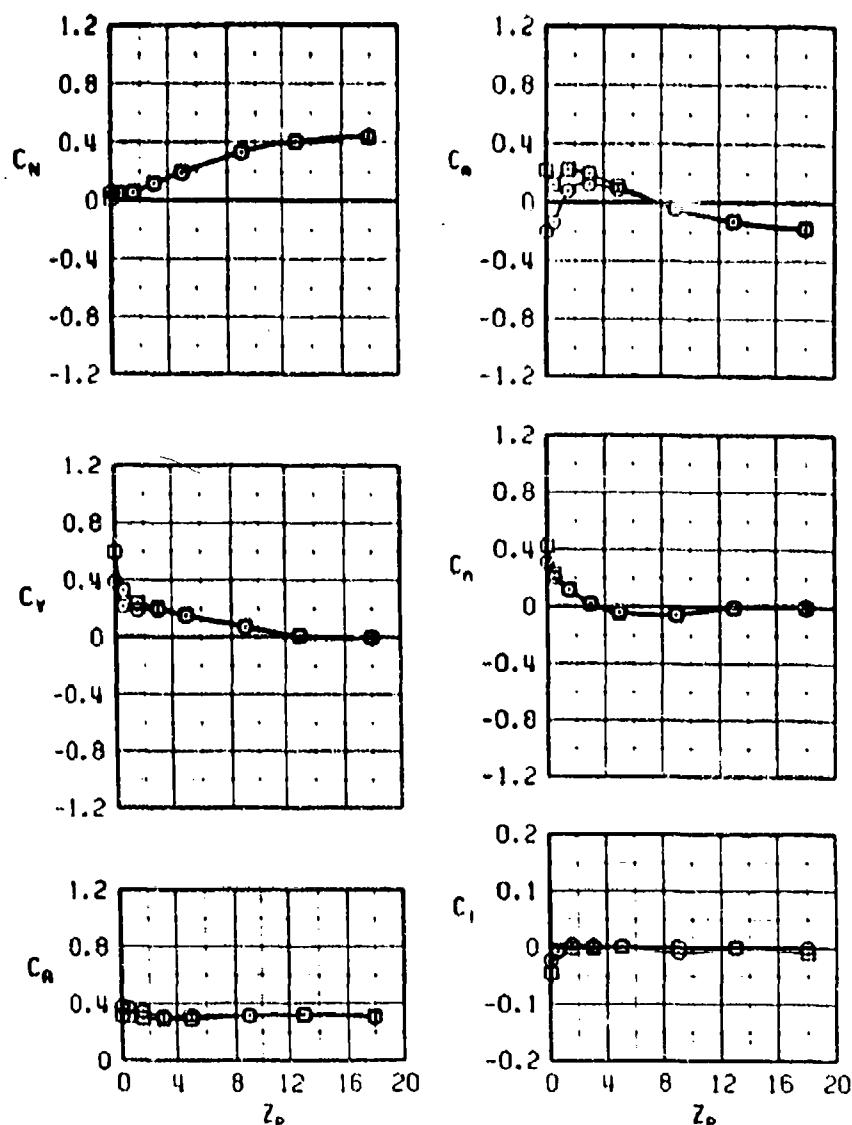


Figure 46. Coefficient variation with wing leading-edge-flap deflection, configuration 17.

Table 1. Metric Model Parameters

	BLU-27 B/B	GBU-8	MK-82SE
b	1.563	1.5	0.896
C_{ℓ_p}	NA	-18.048	-5.0
C_{m_q}	NA	-180.48	-53.0
C_{n_r}	NA	-180.48	-53.0
F_{z_1}	NA	2030.0	1680.0 1113.0*
F_{z_2}	NA	1780.0	1333.3 1900.0*
h	NA	5,000	5,000
I_{xx}	NA	24.7	2.1
I_{yy}	NA	524.2	53.0
I_{zz}	NA	524.2	53.0
\bar{m}	NA	70.243	17.1
S	1.917	1.767	0.630
X_{cg}	5.358	6.608	3.375
X_{L_1}	NA	0.817	1.000
X_{L_2}	NA	-0.850	-0.667
Z_E	NA	0.343	0.343

***Selected Runs**

Table 2. Run Compendium

Conf.	M _x	Store	P.Iom	Rock	Station	Aerodynamic Loads Summary									
						0	1	15	0	2	4	6	10		
1	0.6	BLU-27	7	IFR	2	x				x	x	x	x		
	0.8						x			x	x	x			
	0.9						x			x	x				
	0.95						x			x	x				
2	0.6						x			x	x	x	x	x	
	0.8						x			x	x	x			
	0.9						x			x	x				
	0.95						x			x	x				
3	0.6					3	x			x	x	x	x	x	
	0.8						x			x	x				
	0.9						x			x	x				
	0.95						x			x	x				
4	0.6						x			x	x	x	x	x	
	0.8						x			x	x	x			
	0.9						x			x	x				
	0.95						x			x	x				
5	0.6				NA	NA	x			x	x	x	x	x	
	0.8						x			x	x	x			
	0.9						x			x	x				
	0.95						x			x	x				
6	0.6		6				x			x	x	x	x	x	
	0.8						x			x	x	x			
	0.9						x			x	x				
	0.95						x			x	x				
7	0.6	GBU-8	7	NA	NA	x				x	x	x	x	x	
	0.8						x			x	x	x			
	0.9						x			x	x				
	0.95						x			x	x				
	1.05						x			x					
	1.2						x			x					
8	0.6		6				x			x	x	x	x	x	
	0.8						x			x	x	x			
	0.9						x			x	x				

Table 2. Continued

Cont.	M	Score	MSlow	Block	Station	δ_{14}	Aerodynamic Loads Summary				
							0	1	2	3	4
8	0.95	1.00	S	6	NN	NN	S		X	X	
HC und	1.05						S		X		
	1.2						S		X		
9	0.6			7			S		X	X	X
	0.8						S		X	X	X
	0.9						S		X	X	
	0.95						S		X	X	
	1.05						S		X		
	1.20						S		X		
10	0.4	MK-S2SF	7	1ER	1	K			X		
	0.6						S				X
	0.8						X		X	X	X
	0.9						X		X		
	0.95						S		X	X	
11	0.4				3	X			X		
	0.6					X			X	X	X
	0.8					X			X		
	0.9					X			X	X	
	0.95					X			X	X	
12	0.4				2	X			X		
	0.6					X			X	X	X
	0.8					X			X	X	X
	0.9					X			X	X	
	0.95					X			X	X	

Table 2. Continued

Conf.	M_∞	Store	Pylon	Rack	Station	δ_{1E}			δ_0				
						0	4	15	0	2	4	6	10
13	0.4	MK 92SF	7	MER	1	x				x			
	0.6						x			x	x	x	x
	0.8						x		x	x	x		x
	0.9						x		x	x			
	0.95						x		x	x			
14	0.4		6	MER	6	x			x				
	0.6						x			x	x	x	x
	0.8						x		x	x	x		x
	0.9						x		x	x			
	0.95						x		x	x			
15	0.4		7	NA	NA	x			x				
	0.6						x			x	x	x	x
	0.8						x		x	x	x		
	0.9						x		x	x			
	0.95						x		x	x			
16	0.4		7	NA	NA	x			x				
	0.6						x			x	x	x	x
	0.8						x		x	x	x		x
	0.9						x		x	x			
	0.95						x		x	x			

Table 2. Continued

Cont.	M	Store	Pylon	Back	Station	Aerodynamic Loads Summary				
						0	1	15	0	2
15	0.6	MK 82SE	7	NA	NA	X			X	
	0.8									X
	0.9									
	0.95									
	1.0									
	1.2									

Cont.	M	Store	Pylon	Back	Station	Trajectory Summary				
						0	1	15	0	2
7	0.6	GBU	7	NA	NA	X			X	
	0.8									X
	0.9									X
	0.95									X
	1.0									
	1.2									
R	0.6		6			X			X	
	0.8									X
	0.9									X
	0.95									X
	1.05									X
	1.2									
16	0.6	MK 82SE	7	NA	NA	X			X	
	0.8									X
	0.9									X
	0.95									X
17	0.6		6			X			X	
	0.8									X
	0.9									X
	0.95									X

Table 2. Concluded

Freestream Summary		
Store	M_∞	α_S
BLU-27	0.6	Schedule D
	0.8	
	0.9	
	0.95	
GBU-8	0.6	Schedule B
	0.8	Schedule C
	0.9	Schedule C
	0.95	Schedule B
	1.05	Schedule A
	1.20	Schedule A
MK-82SF	0.4	Schedule D
	0.6	
	0.8	
	0.9	
	0.95	
	1.05	
	1.2	Schedule C

Schedule A: $\alpha_S = -4, -2, 0, 2, 4, 6, 8, 10, 12, 16, 20$

Schedule B: $\alpha_S = -4, -2, 0, 2, 4, 6, 8, 10, 12, 16, 20, 24$

Schedule C: $\alpha_S = -4, -2, 0, 2, 4, 6, 8, 10, 12, 16, 20, 24, 28$

Schedule D: $\alpha_S = -4, -2, 0, 2, 4, 6, 8, 10, 12, 16, 20, 24, 28, 32$

Table 3. Typical Data Uncertainties

Trajectory Data								
Store	M_∞	Δt	ΔX	ΔY	ΔZ	$\Delta \theta$	$\Delta \psi$	$\Delta \phi$
MK-82SF	0.6	0.21	0.008	0.007	0.007	0.12	0.12	NA
MK-82SE	0.95	0.21	0.019	0.015	0.015	0.28	0.28	NA
GBU-8	0.6	0.31	0.004	0.005	0.006	0.32	0.08	1.2
GBU-8	1.2	0.31	0.012	0.017	0.018	0.07	0.25	3.7

Aerodynamic Loads Data									
Store	M_∞	ΔC_N	ΔC_Y	ΔC_A	ΔC_f	ΔC_m	ΔC_M	ΔM_m	Δq_ϕ
BLU-27	0.6	0.010	0.009	0.007	0.003	0.013	0.008	0.005	4.6
	0.8	0.011	0.010	0.007	0.003	0.013	0.010	0.006	2.8
	0.95	0.009	0.009	0.006	0.003	0.011	0.007	0.005	2.4
GBU-8	0.6	0.014	0.010	0.007	0.004	0.026	0.020	0.005	4.6
	0.9	0.012	0.010	0.007	0.003	0.024	0.019	0.006	2.8
	1.2	0.009	0.008	0.007	0.003	0.018	0.015	0.010	2.4
MK 82SE	0.4	0.030	0.030	0.034	0.033	0.047	0.047	0.005	5.4
	0.8	0.020	0.020	0.025	0.023	0.032	0.032	0.005	2.8
	0.95	0.017	0.017	0.021	0.019	0.027	0.027	0.005	2.4

NOMENCLATURE

BL	Aircraft buttock line from plane of symmetry, in., model scale
b	Store reference dimension, ft, full scale
C_A	Store measured axial-force coefficient, axial force/ $q_\infty S$
C_λ	Store rolling-moment coefficient, rolling moment/ $q_\infty Sb$
C_{λ_p}	Store roll-damping derivative, $dC_\lambda/d(pb/2V_\infty)$
C_m	Store pitching-moment coefficient, referenced to the store cg, pitching moment/ $q_\infty Sb$
C_{m_q}	Store pitch-damping derivative, $dC_m/d(qb/2V_\infty)$
C_N	Store normal-force coefficient, normal force/ $q_\infty S$
C_n	Store yawing-moment coefficient, referenced to the store cg, yawing moment/ $q_\infty Sb$
C_{n_r}	Store yaw-damping derivative, $dC_n/d(rb/2V_\infty)$
C_Y	Store side-force coefficient, side force/ $q_\infty S$
FS	Aircraft fuselage station, in., model scale
F_{z_1}	Forward ejector force, lb
F_{z_2}	Aft ejector force, lb
h	Simulated pressure altitude, ft

I_{xx}	Full-scale moment of inertia about the store X_B axis, slug-ft ²
I_{yy}	Full-scale moment of inertia about the store Y_B axis slug-ft ²
I_{zz}	Full-scale moment of inertia about the store Z_B axis, slug-ft ²
M_∞	Free-stream Mach number
\bar{m}	Full-scale store mass, slugs
p_t	Free-stream total pressure, psfa
p_∞	Free-stream static pressure, psfa
q_∞	Free-stream dynamic pressure, psf
S	Store reference area, ft ² , full scale
t	Real trajectory time from initiation of trajectory, sec
V_∞	Free-stream velocity, ft/sec
WL	Aircraft waterline from reference horizontal plane, in., model scale
X	Separation distance of the store cg parallel to the flight axis system X_p direction, ft, full scale measured from the prelaunch position
X_{cg}	Full-scale cg location, ft, from nose of store

x_{L_1}	Forward ejector location relative to the store cg, positive forward to store cg, ft, full scale
x_{L_2}	Aft ejector piston location relative to the store cg, positive forward of store cg, ft, full scale
x_p	Separation distance of the store cg parallel to the pylon axis system X_p direction, ft, full scale measured from the prelaunch position
y	Separation distance of the store cg parallel to the flight axis system Y_f direction, ft, full scale measured from the prelaunch position
y_p	Separation distance of the store cg parallel to the pylon axis system Y_p direction, ft, full scale measured from the prelaunch position
z	Separation distance of the store cg parallel to the flight axis system Z_f direction, ft, full scale measured from the prelaunch position
z_E	Ejector piston stroke length, ft, full scale
z_p	Separation distance of the store cg parallel to the pylon axis system Z_p direction, ft, full scale measured from the prelaunch position
α	Aircraft model angle of attack relative to the free-stream wind vector, deg
α_s	Store model angle of attack relative to the free-stream wind vector, deg

- 0 Angle between the store longitudinal axis and its projection in the $X_F - Y_F$ plane, deg
- ϕ Angle between the projection of the store lateral axis in the $Y_F - Z_F$ plane and the Y_F axis, deg
- ψ Angle between the projection of the store longitudinal axis in the $X_F - Y_F$ plane and the X_F axis, deg

FLIGHT-AXIS SYSTEM COORDINATES

Directions

- X_F Parallel to the free-stream wind vector, positive direction is forward as seen by the pilot
- Y_F Perpendicular to the X_F and Z_F directions, positive direction is to the right as seen by the pilot
- Z_F In the aircraft plane of symmetry, perpendicular to the free-stream wind vector, positive direction is downward

The flight-axis system origin is coincident with the aircraft cg and remains fixed with respect to the parent aircraft during store separation. The X_F , Y_F , and Z_F coordinate axes do not rotate with respect to the initial flight direction and attitude.

STORE BODY-AXIS SYSTEM COORDINATES

Directions

- X_B Parallel to the store longitudinal axis, positive direction is upstream in the prelaunch position

- y_B Perpendicular to the store longitudinal axis, and parallel to the flight-axis system X_F-Y_F plane when the store is at zero roll angle, positive direction is to the right looking upstream when the store is at zero yaw and roll angles
- z_B Perpendicular to both the x_B and y_B axes, positive direction is downward as seen by the pilot when the store is at zero pitch and roll angles

The store body-axis system origin is coincident with the store cg and moves with the store during separation from the parent airplane. The x_B , y_B , and z_B coordinate axes rotate with the store in pitch, yaw, and roll so that mass moments of inertia about the three axes are not time-varying quantities.

PYLON-AXIS SYSTEM COORDINATES

Directions

- x_p Parallel to the aircraft longitudinal axis, positive direction is forward as seen by the pilot
- y_p Perpendicular to the x_p axis and parallel to the flight-axis system X_F-Y_F plane, positive direction is to the right as seen by the pilot
- z_p Perpendicular to both the x_p and y_p axes, positive direction is downward

The pylon-axis system origin is coincident with the store cg in the prelaunch carriage position. The axes are rotated with respect to the flight-axis system by the pitch angles of the aircraft. Both the origin and the direction of the coordinate axes remain fixed with respect to the flight-axis system throughout the trajectory.

SUPPLEMENTARY

INFORMATION

AD-B014360 L

ERRATA

AEDC-TR-76-147 (AFATL-TR-76-113) October 1976
(UNCLASSIFIED REPORT)

AERODYNAMIC LOADS AND SEPARATION CHARACTERISTICS OF THE BLU-27B/B, MK-82SE, AND GBU-8 WEAPONS IN THE F-16 AIRCRAFT FLOW FIELD AT MACH NUMBERS FROM 0.4 TO 1.2

E. G. Allee, Jr., ARO, Inc.

Arnold Engineering Development Center
Air Force Systems Command
Arnold Air Force Station, Tennessee

The X_{cg} value of 6.608 quoted for the GBU-8 store in
Table 1 should have been 5.135.

Please substitute the corrected table in your copy of
the report.

Table 1. Metric Model Parameters

	BLU-27 B/B	GBU-8	MK-82SE
b	1.563	1.5	0.896
C_{l_p}	NA	-18.048	-5.0
C_{m_q}	NA	-180.48	-53.0
C_{n_r}	NA	-180.48	-53.0
F_{z_1}	NA	2030.0 1113.0*	1680.0 1900.0*
F_{z_2}	NA	1780.0	1333.3 1900.0*
h	NA	5,000	5,000
I_{xx}	NA	24.7	2.1
I_{yy}	NA	524.2	53.0
I_{zz}	NA	524.2	53.0
m	NA	70.243	17.1
s	1.917	1.767	0.630
X_{cg}	5.358	5.135	3.375
X_{L_1}	NA	0.817	1.000
X_{L_2}	NA	-0.850	-0.667
Z_E	NA	0.343	0.343

*Selected Runs